

# SCIENTIFIC AMERICAN MIND

PLUS

CONFOUNDING NEW  
ALZHEIMER'S DRUG

THE PARTICULAR  
GRIEF OF WAITING  
FOR BAD NEWS

HOW TO RAISE  
KIND KIDS

## IT'S IN THE EYES

A surprising new correlation  
has been discovered between  
pupil size and intelligence

FROM  
THE  
EDITOR



Liz Tormes

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# On Kindness and Grief

After a large portion of a Miami-area apartment building spontaneously collapsed in June, *Scientific American* contributor Katherine Harmon Courage sat down with social scientist and clinician Pauline Boss to learn about the particular sort of grief that comes with ambiguous loss. Such losses occur when, for example, a relative's remains cannot be recovered from an accident or when a child goes missing. Chances are that the person is gone, but there is no certainty. Something about that kind of uncertainty rings very true amid the stress and anxiety of the pandemic—not knowing if you or a loved one will get sick, or if your job is secure, or how to balance child care and COVID restrictions. Boss tells our reporter how humans can build their tolerance for living with ambiguity. But I imagine it doesn't make it any less difficult (see "[Ambiguous Loss from Miami-Area Condo Collapse Makes Grieving Harder](#)"). As numerous psychological studies have shown, no matter the flavor, grief requires patience and compassion—especially toward the self.

This issue is full of other fascinating findings. Research now suggests that human smarts may be gleaned by, of all things, certain dimensions of the eyeball (see "[Pupil Size Is a Marker of Intelligence](#)"). And senior editor Clara Moskowitz picks the brain of Melinda Wenner Moyer, whose new book details the scientific ways to teach children to be generous, honest, helpful and kind (see "[How to Raise Kids Who Don't Grow Up to Be Jerks \(or Worse\)](#)"). Kindness sometimes feels in short supply in today's world. Best we nurture it in our own homes.

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### On the Cover

A surprising new correlation has been discovered between pupil size and intelligence

## NEWS

### 4. Pupil Size Is a Marker of Intelligence

There is a surprising correlation between baseline pupil size and several measures of cognitive ability

### 5. Neck-Zapping Gadget Reduced All-Nighter Fatigue in New Study

And the benefits of two four-minute sessions persisted for hours

### 8. Injection of Light-Sensitive Proteins Restores Blind Man's Vision

The first successful clinical test of optogenetics lets a person see for the first time in decades, with help from image-enhancing goggles

### 9. How to Raise Kids Who Don't Grow Up to Be Jerks (or Worse)

A new book gives science-based advice for parenting kids to be generous, kind antiracists



### 11. News about Racial Violence Harms Black People's Mental Health

Awaiting the Derek Chauvin verdict, a singer and actor felt intense anxiety

### 13. Gray Hair Can Return to Its Original Color—and Stress Is Involved, Of Course

The universal marker of aging is not always a one-way process

### 15. New Brain Implant Transmits Full Words from Neural Signals

No spelling out of letters is needed for a paralyzed person to use the first-of-a-kind neuroprosthesis

### 16. It's Not You, It's COVID: Couples Who Blamed Pandemic for Tensions Stayed Happier

Pinning stress on the coronavirus helped couples cope and remain resilient



## FEATURES

### 19. Landmark Alzheimer's Drug Approval Confounds Research Community

Many scientists say there is not enough evidence that Biogen's aducanumab is an effective therapy for the disease

### 22. Ambiguous Loss from Miami-Area Condo Collapse Makes Grieving Harder

In a Q&A, loss expert Pauline Boss talks about coping with extreme uncertainty in the wake of a disaster

### 25. How Did Neandertals and Other Ancient Humans Learn to Count?

Archaeological finds suggest that people developed numbers tens of thousands of years ago. Scholars are now exploring the first detailed hypotheses about this life-changing invention

### 30. Inspired by Chronic Illness, She Made Award-Winning Art about the Brain

*Scientific American* presents the winner and honorable mentions of the 11th annual Art of Neuroscience contest

## OPINION

### 33. The Neuroscience of Taking Turns in a Conversation

Research in birds suggests that when one partner speaks, the other partner's brain is inhibited from talking over them

### 35. Psychiatry Needs to Get Right with God

By not making more of an effort to incorporate spirituality in treatment, we are doing a disservice to patients

### 38. A New Mental Health Crisis Is Raging in Gaza

Recent bombings by Israel have caused more than just physical trauma

### 41. Science Should Not Try to Absorb Religion and Other Ways of Knowing

Our diverse ways of seeing reality will never, and should never, meld into a monolithic worldview

## ILLUSIONS

### 44. No Shrinking Violet

How Impressionist painters made an unusual color all the rage

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## Pupil Size Is a Marker of Intelligence

**There is a surprising correlation between baseline pupil size and several measures of cognitive ability**

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It has been said that “the eyes are the window to the soul,” but new research suggests that they may be a window to the brain as well.

Our pupils respond to more than just the light. They indicate arousal, interest or mental exhaustion. Pupil dilation is even used by the FBI to detect deception. Now work by our laboratory at the Georgia Institute of Technology suggests baseline pupil size is closely related to individual differences in intelligence. The larger the pupils, the higher the intelligence, as measured by tests of reasoning, attention and memory. In fact, across three studies, we found that the difference in baseline pupil size between

people who scored the highest on the cognitive tests and those who scored the lowest was large enough to be detected by the unaided eye.

We uncovered this surprising relationship while studying differences in the amount of mental effort people used to complete memory tasks. We

used pupil dilations as an indicator of effort, a technique psychologist Daniel Kahneman popularized in the 1960s and 1970s. When we discovered a relationship between baseline pupil size and intelligence, we weren't sure if it was real or what it meant.

Intrigued, we conducted several

large-scale studies in which we recruited more than 500 people aged 18 to 35 from the Atlanta community. We measured participants' pupil size using an eye tracker, a device that captures the reflection of light off the pupil and cornea using a high-powered camera and computer.



We measured participants' pupils at rest while they stared at a blank computer screen for up to four minutes. All the while, the eye tracker was recording. Using the tracker, we calculated each person's average pupil size.

To be clear, pupil size refers to the diameter of the black circular aperture in the center of the eye. It can range from around two to eight millimeters. The pupil is surrounded by the colorful area known as the iris, which is responsible for controlling the size of the pupil. Pupils constrict in response to bright light, among other things, so we kept the laboratory dim for all participants.

In the next part of the experiment, participants completed a series of cognitive tests designed to measure "fluid intelligence," the capacity to reason through new problems, "working memory capacity," the ability to remember information over a period of time, and "attention control," the ability to focus attention amid distractions and interference.

As one example of an attention control test, participants had to resist glancing toward a bold, flickering asterisk on one side of a computer screen and instead rapidly look in the opposite direction to identify a letter.

The letter would disappear within moments, so even a brief eye movement toward the flickering asterisk could result in missing it. Humans are primed to react to objects passing through their peripheral vision—it's what once allowed us to spot a predator or prey—but this task required participants to redirect their focus from the flicking asterisk to the letter.

We found that a larger baseline pupil size was correlated with greater fluid intelligence, attention control and, to a lesser degree, working memory capacity—indicating a fascinating relationship between the brain and eye. Interestingly, pupil size was negatively correlated with age: older participants tended to have smaller, more constricted, pupils. Once standardized for age, however, the relationship between pupil size and cognitive ability remained.

But why does pupil size correlate with intelligence? To answer this question, we need to understand what is going on in the brain. Pupil size is related to activity in the locus coeruleus, a nucleus situated in the upper brain stem with far-reaching neural connections to the rest of the brain. The locus coeruleus releases norepinephrine, which functions as

both a neurotransmitter and hormone in the brain and body, and it regulates processes such as perception, attention, learning and memory. It also helps maintain a healthy organization of brain activity so that distant brain regions can work together to accomplish challenging tasks and goals. Dysfunction of the locus coeruleus, and the resulting breakdown of organized brain activity, has been related to several conditions, including Alzheimer's and attention deficit hyperactivity disorder. This organization of activity is so important that the brain devotes most of its energy to maintain it, even when we are not doing anything at all—such as when we stare at a blank computer screen for minutes on end.

One hypothesis is that people who have larger pupils at rest have greater regulation of activity by the locus coeruleus, which benefits cognitive performance and resting-state brain function. More research is needed to explore this possibility and determine why larger pupils are associated with higher fluid intelligence and attention control. But it's clear that there is more happening than meets the eye.

—Jason S. Tsukahara and Alexander P. Burgoyne

## Neck-Zapping Gadget Reduced All-Nighter Fatigue in New Study

And the benefits of two four-minute sessions persisted for hours

Instead of reaching for a cup of coffee during a graveyard shift, workers might one day hold an electric-razor-sized device to their neck. After a couple of minutes, they would emerge refreshed and awake from this experience, which could come to be known as a "vagus nerve break."

The device, called gammaCore, sends a series of vibrating bursts of low-voltage electricity, each lasting a millisecond, to the side of the neck. It is meant to stimulate part of the vagus nerve, a connector between brain and body, and cause the release of wakefulness chemicals.

Research on a way to keep people awake and alert with electricity began after scientists affiliated and contracted with the U.S. Air Force noted that participants who had electrodes placed onto their scalps to deliver a current were able to

lower fatigue and improve their performance on attention tasks. This setup is not easy to re-create outside of a lab, but if it were, it could offer an alternative to caffeine or amphetamine stimulants, also known as “go pills,” which are still prescribed to U.S. Air Force soldiers.

Looking for a more direct and side-effect-free solution led researchers to the vagus nerve. Surgical implants that stimulate the nerve have been used to prevent seizures in people with epilepsy since 1988, and some of these patients have found that the implant helped them manage their headaches and pain. Other studies have found that implanted vagus nerve stimulation improved memory and cognition in both humans and animals.

New research provides confirmation that handheld vagus nerve stimulation does what scientists thought it might: gammaCore helped members of the Air Force perform better and feel less fatigued when pulling an all-nighter. Study results were published in June in the journal *Communications Biology*.

Many thought stimulating the vagus nerve without needles or surgery was impossible before the



Air Force soldier demonstrates the use of gammaCore.

technology was invented a decade ago, says Peter Staats, chief medical officer and co-founder of electroCore, the company that makes gammaCore. The handheld device works by touching conductive gel on the skin’s surface, and it was first approved to treat cluster headaches in adults in 2017. Since then, its use has been expanded to include adult and adolescent migraines, and it has received emergency use authorization for asthma worsened by

COVID-19 in adults. The device is covered by several major pharmacy benefit managers when it is prescribed, and its list price is \$1,750, although the company says it has been offering gammaCore to all customers for \$1,250 for now. (An electroCore spokesperson notes the newest model can cost as low as \$399 for three months of treatment.)

Vagus nerve stimulation is a popular target for bioelectronic medicine because of the direct links



GammaCore device

between the nerve and many of the body’s organs. Stephen Silberstein, a neurology professor at Thomas Jefferson University and director of the Jefferson Headache Center, compares the vagus nerve to a major transportation hub such as Grand Central Terminal in New York City, where hopping on a train can send a commuter anywhere in the metropolitan area. Similarly, different types of fibers travel to different places, including a part of the brain called the locus coeruleus. There the brain produces norepinephrine, a fight-or-flight chemical that increases alertness and decreases pain and tiredness.

In the study, researchers observed 40 active-duty soldiers from an Air Force base as they stayed awake for 34 hours, during which time they completed cognitive tests and

reported their mood and level of fatigue. Half of the participants used gammaCore for eight minutes near the beginning of testing, while the other half were given a sham device that looked and felt like the real deal but did not provide an electric current. Those in the group that received the real vagus nerve stimulation stuck more closely to their baseline performance as the night wore on and reported less fatigue over time than the other group.

“It’s exciting to us that not only do they perform better, but they also perceive that they’re performing better and that they feel less tired,” says Richard McKinley, a co-author of the study and a biomedical engineer at the Air Force Research Laboratory. He says that improvements in mood and energy level could motivate the soldiers to use a device like this outside of a paid study.

While the two groups performed similarly over time on some portions of the cognitive testing, hours later, the participants who used gammaCore showed less performance decline in perception-related tasks—taking in and synthesizing audio, visual or other kinds of information.

Past research on gammaCore and

vagus nerve stimulation has targeted populations with chronic and often debilitating conditions such as rheumatoid arthritis, migraine headaches and epilepsy. This new work is leading the charge to use this therapy on healthy people for performance enhancement, Staats and the study’s authors say.

“Much of what we do in Western medicine is we try to help people who have already got diseases,” Staats says. “We spend less effort thinking about health regimens or ‘How do we avoid development of diseases?’ or ‘How do we optimize ourselves?’ ”

Silberstein, who was not involved in the study, says this device could help a wide range of sleep-deprived individuals, from Air Force pilots to doctors to college students writing last-minute papers.

Another group that might benefit from the research is astronauts. Lindsey McIntire, the paper’s first author and a scientist at the defense-contracted company Infoscitex, says that NASA provided some of the study’s funding because astronauts often sleep in extreme and unfamiliar environments, leading to less restful slumber. Finding a long-lasting solution to fatigue would keep

**“Much of what we do in Western medicine is we try to help people who have already got diseases.”**

*—Peter Staats*

people happier, healthier and more focused on their tasks in space.

Eric Chang, a professor at the Feinstein Institutes for Medical Research, who was also not involved in the research, says its findings may not be generalizable to people who are not continuously sleep-deprived for 34 straight hours, as the participants were. He adds that the study reports a “specific, small result” in line with other vagus nerve stimulation studies.

McIntire notes that differences in performance between the gammaCore and placebo groups that may appear small—such as in the multi-tasking test—can have big implications. “Performance for the active group declined 5 percent, but it declined to 15 percent for [the placebo group],” she says. “That’s mistakes, and in certain fields like medicine and the military and transportation, that can equal lives.” The authors are also planning

research to examine effects in people with milder sleep deprivation.

McIntire says future studies need to be done before gammaCore can be recommended to soldiers and workers for off-label use, including testing it against caffeine and other conventional stimulants. McKinley adds that concurrent studies in animals are double-checking the effect’s mechanism. He is also preparing to submit research on vagus nerve stimulation to boost learning rates and retention.

GammaCore owes its invention to the relatively new field of bioelectric medicine, a discipline that uses electricity to hack into the body’s signaling system to treat disease. Bioelectronic medicine has shown promise in treating autoimmune diseases such as lupus through vagus nerve stimulation. Tiredness, pain, inflammation—future “vagus nerve breaks” could target them all.

*—Maddie Bender*

## Injection of Light-Sensitive Proteins Restores Blind Man's Vision

The first successful clinical test of optogenetics lets a person see for the first time in decades, with help from image-enhancing goggles

After 40 years of blindness, a 58-year-old man can once again see images and moving objects, thanks to an injection of light-sensitive proteins into his retina.

The study, published on May 24 in *Nature Medicine*, is the first successful clinical application of a technique called optogenetics, which uses flashes of light to control gene expression and neuron firing. The technique is widely used in laboratories to probe neural circuitry and is being investigated as a potential treatment for pain, blindness and brain disorders.

The clinical trial, run by the company GenSight Biologics, headquartered in Paris, enrolled people with retinitis pigmentosa (RP): a degenerative disease that kills off the eye's photo-

receptor cells, which are the first step in the visual pathway. In a healthy retina, photoreceptors detect light and send electrical signals to retinal ganglion cells (RGCs), which then transmit the signal to the brain. GenSight's optogenetic therapy skips the damaged photoreceptor cells entirely by using a virus to deliver light-sensitive bacterial proteins into the RGCs, allowing them to detect images directly.

The researchers injected the virus into the eye of a man with RP, then waited four months for the RGCs to begin producing the proteins before testing his vision. Ophthalmologist José-Alain Sahel of the University of Pittsburgh Medical Center in Pennsylvania, who led the study, says that one of the challenges was regulating the amount and type of light entering the eye, since a healthy retina uses a variety of cells and light-sensitive proteins to see a wide range of light. "No protein can replicate what the system can do," he says. So the researchers engineered a set of goggles that capture the images around the man and optimize them for detection by the bacterial proteins.

Using a camera, the goggles analyze changes in contrast and



brightness and convert them in real time into what Sahel describes as a "starry sky" of amber-colored dots. When the light from these dots enters a person's eye, it activates the proteins and causes the RGCs to send a signal to the brain, which then resolves these patterns into an image.

The man taking part in the trial had to train with the goggles for several months before his brain adjusted to interpret the dots correctly. "He was like an experimentalist, a scientist trying to understand what he was seeing and make sense of it," Sahel

says. Eventually, he was able to make out high-contrast images, including objects on a table and the white stripes in a crosswalk. When the researchers recorded his brain activity, they found that his visual cortex reacted to the image in the same way as it would if he had normal sight.

The man still can't see without the goggles, but Sahel says that he wears them for several hours per day and that his vision has continued to improve in the two years since his injection. Six other people were



injected with the same light-sensitive proteins last year, but the COVID-19 epidemic delayed their training with the goggles. Sahel says he expects to have their results within about a year.

**SAFE AND PERMANENT**

“It’s a big step for the field,” says John Flannery, a neurobiologist at the University of California, Berkeley. “The most important thing is that it seems to be safe and permanent, which is really encouraging.” Because the retina contains around 100 times more photoreceptors than RGCs, the resolution of images detected by RGCs will never be as good as natural vision. But Flannery says it is exciting that the brain can interpret images accurately.

Others say that more research is needed. “It’s interesting, but it’s an N of 1,” says Sheila Nirenberg, a neuroscientist at Weill Cornell Medical College in New York City. She adds that she looks forward to seeing whether the other people in the trial, including some who were injected with higher doses of the protein, have similar results.

GenSight is one of several companies developing optogenetics as a treatment for RP and other disorders

of the retina. In March, Nirenberg’s company Bionic Sight announced that four of the five people with RP it treated with a similar optogenetic therapy and a VR headset had recovered some level of vision, although the full trial results have not yet been published. And Swiss pharma giant Novartis is developing a therapy based on a different protein that is so light sensitive that goggles may not be needed. That therapy has not yet entered clinical trials.

Neuroscientist Karl Deisseroth from Stanford University in California, who co-developed optogenetics as a laboratory technique, says the study is important because it is the first time that its effects have been shown in people. “It will be interesting to try this with more light-sensitive opsins” that might not require goggles, he says. But he expects optogenetics to be most useful as a research tool that leads to therapies rather than a therapy itself. “What we hope to see even more of is optogenetics-guided human and clinical studies,” he says.

—Sara Reardon

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**How to Raise Kids Who Don’t Grow Up to Be Jerks (or Worse)**

**A new book gives science-based advice for parenting kids to be generous, kind antiracists**

There is no shortage of parenting advice in books and on the Internet, much of it conflicting: for instance, “Do sleep train your baby” versus “Don’t, under any circumstances, sleep train your baby.” But the vast

majority of this guidance is based on anecdotal experience and personal belief—very little of it relies on evidence, found science writer Melinda Wenner Moyer, a parent of two. She set out to discover what science has to say about one of the most profound questions a parent can ask: “How do I raise my children to help make the world a better place?”

In other words, “How can I make sure my kids don’t turn into selfish boors?” In her new book *How to Raise Kids Who Aren’t Assholes* (G. P. Putnam’s Sons), which came out this summer, Moyer probes the research on how to encourage kids to be

generous, honest, helpful and kind. She reviews studies on how to instill egalitarian beliefs and make sure kids know how to stand up against racism and sexism. And she talks to scientists about perennial parental struggles such as sibling rivalry, teaching safe sex and moderating screen time. *Scientific American* spoke to Moyer about science-based strategies for raising good citizens.

[An edited transcript of the interview follows.]

***I love that this book addresses so many questions and insecurities I have as a parent. Why did you decide to write it?***

I want my kids to be compassionate, kind, generous antiracists and antisexist. And I thought, “I can learn about how to raise my kids in these ways and to instill values based on science rather than just relying on my instincts.” I was surprised by just how much research there was on these questions and how little of it was being covered.

There is already so much pressure on parents these days. I don’t want to tell other parents what to do. But if I could write a book that gives parents tools that could change the world for

## How to Raise Kids Who Aren’t Assholes

Science-based  
Strategies for  
Better Parenting—  
from  
Tots to Teens



Melinda Wenner Moyer

the better, that feels important. I want this book to make parents’ lives easier, to give them answers to questions they might have had and to give them the science and tools they’ve been looking for. I don’t want to add to their burdens or add to the judgment that parents are under right now.

***Were there any cases where you found the science went against what you previously thought and surprised you?***

One of the core questions I had was, “How do I raise my kids to be generous and kind?” A lot of what we hear is about the importance of teaching giving and generosity. But the research I kept coming across stemmed from how we talk about

feelings. That’s surprising—why would that have anything to do with how generous children would become? It became clear that helping our kids understand their feelings gives them the capacity to understand others’ feelings and helps them make decisions to help their friends and be more generous toward them. This is part of something called theory of mind—how to understand others’ feelings. Research suggests that the more parents talk about their feelings and other peoples’, the more kids are likely to be generous and helpful.

***What does science tell us about raising kids to be antiracist?***

Parents often think if we don’t talk about race, our children won’t see it, won’t develop racism. That is, in fact, the opposite of what happens. Kids see race from a very early age and are very tuned in to social hierarchies. They are like little detectives trying to figure out how social categories work in the world and why. They see that most American presidents have been white and that a lot of the kids at school who have the biggest houses, their parents are white. They think the simplest explanation is that white people are just better or smarter. The

research shows we need to correct these misconceptions as children are developing them. We need to talk about it quite a lot, which is really hard for white parents; it’s hard for me. Some of these approaches I learned for the book are hard. They take practice and are not instinctual, but the research shows those difficult conversations help even if they’re not perfect.

***I have a four-year-old daughter, and I don’t think she has any idea yet that anyone thinks girls aren’t just as good as boys. Is it really helpful to introduce her to the idea of sexism?***

I had the same question, and I posed this to the researchers. My daughter and I were reading *Good Night Stories for Rebel Girls*, and every story we read touched upon the sexism these women experienced and overcame. I kept thinking it was hitting my daughter over the head with the idea that she’d have to fight sexism. But I found that no, actually, they are already perceiving it often on some level, even if they’re not bringing it up. They’re seeing the presidents are all men, all these powerful people are all men. They notice. When we do bring it up and

talk about it, it helps them work through it. It is counterintuitive.

***One of the interesting things you write about is that parents often worry their child will be bullied and rarely worry their child will be a bully.***

We have this idea that there is a type of kid that is a bully. But it's not just a bad seed who becomes a bully. Anybody can bully. We need to have regular conversations with our kids about this. Some of the research has found that kids who engage in bullying behaviors often don't realize their behavior is hurtful. It comes back to the idea of talking about feelings. Sometimes they aren't intentionally trying to hurt other people—they don't understand the impact of what they're doing.

***Another fascinating chapter is about the dangers of pressuring kids for academic success.***

That was a chapter that blew me away. I was surprised to find that our well-meaning desires for our kids to succeed and achieve can be so harmful to self-esteem. I was reading the research and thinking, "Am I doing this? Am I turning my child into a

monster?" We all just want our kids to do better and better. We're worried about getting our kids into college, and our fears are grounded—it's harder than it used to be. But if we aren't careful, we can actually seed the very problems we're trying to avoid. If kids are constantly questioning themselves because they feel our love is contingent on how well they do and their grades, they're going to have so many issues with self-esteem.

***Science is still trying to figure out how much nature and nurture affect personality. Do parents have a lot of room to influence who their kids will turn out to be?***

I think genetics certainly play a role, but it's clear that environment and parenting do, too. We might have kids that start in different places with their propensity to be generous or have these other traits, but we can still move them in the right direction through how we parent. I observe that my two children have very different personalities and different inclinations toward generosity and empathy. But as I learned to parent through the techniques I talk about in the book, I've seen both of them change.

—Clara Moskowitz

## News about Racial Violence Harms Black People's Mental Health

**Awaiting the Derek Chauvin verdict, a singer and actor felt intense anxiety**

For months, Desmond Ellington assiduously refused to watch the videotaped killing of George Floyd. When former Minneapolis police officer Derek Chauvin went on trial for his murder, Ellington did not turn on the television until he saw a headline on his smartphone that the verdict would be announced within the hour. It was not that he did not care about what was happening; it was that he cared too much.

For the 37-year-old Black singer and actor, the news accounts and social media videos of racial violence and the killings of unarmed Black people that too often go unpunished were not just demoralizing, they were traumatizing. "It gets to the point where you decide, 'I have to turn off the television because I have my sanity to take care of,'" says Ellington,

an Arkansas native who lives in New York. "It's like a sadness, a hopelessness. Those images just keep coming like weeds. You pick one weed, and two more sprout up. So you gonna set the whole yard on fire to kill the weeds? It wears on your psyche."

A growing body of research has documented the detrimental effects of both interpersonal and structural racism. The Centers for Disease Control and Prevention notes that centuries of racism have had a profound and negative impact on the mental and physical health of people of color. Investigators at Columbia University found that experiencing racism can result in traumatic stress linked to negative mental health outcomes, such as depression, anger and low self-esteem. The American Public Health Association calls racism a social determinant of health akin to housing, education, and employment and a barrier to health equity.

A study recently published in the *Proceedings of the National Academy of Sciences USA* adds a new layer to an understanding of the pervasive health effects of racism. Lead author David Curtis of the University of Utah and his colleagues showed that widely publicized anti-Black violence

negatively affects the mental health of many Black Americans even if they do not directly experience it.

The study's authors conducted the first nationwide scientific assessment of these media reports using 49 high-profile incidents that occurred between 2013 and 2017. They included media reports of 38 police killings of Black individuals, as well as coverage of about nine legal decisions not to indict or convict officers involved in some of those killings.

Using weekly data from the Behavioral Risk Factor Surveillance System survey, the researchers assessed the mental health impacts on people during this period. Black respondents reported more poor mental health days during the time when two or more of these events happened in the country. Legal decisions not to prosecute or convict the officers involved in the killings were most clearly associated with poor mental health days, Curtis says. This reflects Black people's concern and dismay about what they see as the systemic injustice that follows a much publicized incident and the failure to hold anyone accountable more than their reaction to the initial wrong perpe-

**“I have to know how to conduct myself when I’m out. I’m always thinking, ‘Am I walking or standing too close to this person?’ ”**  
*—Desmond Ellington*

trated by any single individual.

Those emotions also resonate with personal experiences in which racism is ever present. As a senior operations engineer who is starting a job at Amazon later this month, 26-year-old Adam Williams works in a field in which Black people are dramatically underrepresented. That mirrors his life on a college campus just a few years ago. When he graduated from Purdue University in 2017, just 1.6 percent of the students in the College of Engineering were Black, a statistic that figured into the way he was perceived.

Initially, none of Williams's classmates wanted to be his lab partner, and they seemed shocked when he



answered questions correctly in class. “I saw Nazi propaganda scattered across campus detailing how I was genetically inferior,” he says of literature disparaging Black people. “I was hastily labeled a delinquent, followed through stores, questioned by police under bogus pretenses and frequently assumed that the only way I could be at Purdue was as an athlete.”

For his part, Ellington considers himself lucky to have encountered little overt and direct racism. Yet

despite achieving a measure of professional success and traveling the country as a member of the cast of *Hamilton*, he cannot shake the feeling that he is just one wrong move away from becoming another statistic.

“I’m still very aware that it could happen to me,” he says. “I have to know how to conduct myself when I’m out. I’m always thinking, ‘Am I walking or standing too close to this person?’ It’s a burden that I have to be in that box so I can get back home to

my family. It's so emotionally and physically draining. You don't even realize how much until you see another Black man get shot. I think it's in those moments you realize how much of a burden it is to be Black in America."

Psychologist Vanessa Volpe runs the Black Health Lab at North Carolina State University, where she studies the impact of direct and vicarious racism on physical health. She compares the kind of hypervigilance Ellington talks about—trying to navigate the thicket of structural, systemic and interpersonal racism—to driving a car with the parking brake on.

"Because exposure to racism is chronic, frequent and can happen at any time, you have to be vigilant to protect yourself," Volpe says. "Over time, your body is going to experience this wear and tear that will result in much greater rates of morbidity and earlier mortality for Black folks, compared to white people. A lot of times we think, 'Just get a better car or replace the parking brake,' but that's a Band-Aid. What can we do so that Black people don't even have that exposure in the first place?"

—Melba Newsome

## Gray Hair Can Return to Its Original Color—and Stress Is Involved, Of Course

The universal marker of aging is not always a one-way process

Few harbingers of old age are clearer than the sight of gray hair. As we grow older, black, brown, blonde or red strands lose their youthful hue. Although this may seem like a permanent change, new research reveals that the graying process can be undone—at least temporarily.

Hints that gray hairs could spontaneously regain color have existed as isolated case studies within the scientific literature for decades. In one 1972 paper, the late dermatologist Stanley Comaish reported an encounter with a 38-year-old man who had what he described as a "most unusual feature." Although the vast majority of the individual's hairs were either all black or all white, three strands were light near the ends but dark near the roots. This signaled a reversal in the normal graying process, which begins at the root.



In a study published in June in *eLife*, a group of researchers provide the most robust evidence of this phenomenon to date in hair from around a dozen people of various ages, ethnicities and sexes. It also aligns patterns of graying and reversal to periods of stress, which implies that this aging-related process is closely associated with our psychological well-being.

These findings suggest "that there

is a window of opportunity during which graying is probably much more reversible than had been thought for a long time," says study co-author Ralf Paus, a dermatologist at the University of Miami.

Around four years ago Martin Picard, a mitochondrial psychobiologist at Columbia University, was pondering the way our cells grow old in a multistep manner in which some of them begin to show signs of aging

at much earlier time points than others. This patchwork process, he realized, was clearly visible on our head, where our hairs do not all turn gray at the same time. “It seemed like the hair, in a way, recapitulated what we know happens at the cellular level,” Picard says. “Maybe there’s something to learn there. Maybe the hairs that turn white first are the more vulnerable or least resilient.”

While discussing these ideas with his partner, Picard mentioned something in passing: if one could find a hair that was only partially gray—and then calculate how fast that hair was growing—it might be possible to pinpoint the period in which the hair began aging and thus ask the question of what happened in the individual’s life to trigger this change. “I was thinking about this almost as a fictive idea,” Picard recalls. Unexpectedly, however, his partner turned to him and said she had seen such two-colored hairs on her head. “She went to the bathroom and actually plucked a couple—that’s when this project started,” he says.

Picard and his team began searching for others with two-colored hairs through local ads, on social media and by word of mouth. Eventually,

they were able to find 14 people—men and women ranging from nine to 65 years old with various ethnic backgrounds (although the majority were white). Those individuals provided both single- and two-colored hair strands from different parts of the body, including the scalp, face and pubic area.

The researchers then developed a technique to digitize and quantify the subtle changes in color, which they dubbed hair pigmentation patterns, along each strand. These patterns revealed something surprising: In 10 of these participants, who were between age nine and 39, some graying hairs regained color. The team also found that this occurred not just on the head but in other bodily regions as well. “When we saw this in pubic hair, we thought, ‘Okay, this is real,’” Picard says. “This happens not just in one person or on the head but across the whole body.” He adds that because the reversibility only appeared in some hair follicles, however, it is likely limited to specific periods when changes are still able to occur.

Most people start noticing their first gray hairs in their 30s—although some may find them in their late 20s.

This period, when graying has just begun, is probably when the process is most reversible, according to Paus. In those with a full head of gray hair, most of the strands have presumably reached a “point of no return,” but the possibility remains that some hair follicles may still be malleable to change, he says.

“What was most remarkable was the fact that they were able to show convincingly that, at the individual hair level, graying is actually reversible,” says Matt Kaeberlein, a biogerontologist at the University of Washington, who was one of the editors of the new paper but was not involved in the work. “What we’re learning is that, not just in hair but in a variety of tissues, the biological changes that happen with age are, in many cases, reversible—this is a nice example of that.”

The team also investigated the association between hair graying and psychological stress because prior research hinted that such factors may accelerate the hair’s aging process. Anecdotes of such a connection are also visible throughout history: according to legend, the hair of Marie Antoinette, the 18th-century queen of France,

turned white overnight just before her execution at the guillotine.

In a small subset of participants, the researchers pinpointed segments in single hairs where color changes occurred in the pigmentation patterns. Then they calculated the times when the change happened using the known average growth rate of human hair: approximately one centimeter per month. These participants also provided a history of the most stressful events they had experienced over the course of a year.

This analysis revealed that the times when graying or reversal occurred corresponded to periods of significant stress or relaxation. In one individual, a 35-year-old man with auburn hair, five strands of hair underwent graying reversal during the same time span, which coincided with a two-week vacation. Another subject, a 30-year-old woman with black hair, had one strand that contained a white segment that corresponded to two months during which she underwent marital separation and relocation—her highest-stress period in the year.

Eva Peters, a psychoneuroimmunologist at the University Hospital of Giessen and Marburg in Germany,

who was not involved in this work, says that this is a “very creative and well-conceptualized study.” But, she adds, because the number of cases the researchers were able to look at was relatively small—particularly in the stress-related portion of the study—further research is needed to confirm these findings.

For now, the next step is to look more carefully at the link between stress and graying. Picard, Paus and their colleagues are currently putting together a grant to conduct another study that would examine changes in hair and stress levels prospectively—which means tracking participants over a specified period of time rather than asking them to recall life events from the past.

Eventually, Picard says, one could envision hair as a powerful tool to assess the effects of earlier life events on aging—because, much like the rings of a tree, hair provides a kind of physical record of elapsed events. “It’s pretty clear that the hair encodes part of your biological history in some way,” he says. “Hair grows out of the body, and then it crystallizes into this hard, stable [structure] that holds the memory of your past.”

—Diana Kwon

## New Brain Implant Transmits Full Words from Neural Signals

No spelling out of letters is needed for a paralyzed person to use the first-of-a-kind neuroprosthesis

More than 15 years ago a man who was only 20 years old had a massive stroke when a major artery supplying his brain stem burst. The incident left him unable to control his limbs or any muscles related to speech. With a device that relied on his head motions to control a keyboard, he could produce about five words a minute, one character at a time. The typical rate when someone is speaking fluidly can be up to 200 words a minute.

Now he is the first person ever to produce whole words via a computer intermediate that decodes his brain’s messages. A processor connected to an array of electrodes implanted in his brain receives the messages and translates them into words displayed on a screen. As researchers reported on July 14 in the *New England Journal of Medicine*, the man, who is



Neurosurgeon Edward Chang, who performed the neuroprosthetic surgery.

now in his late 30s, used this brain-computer interface, or BCI, to produce whole words outside of his brain for the first time since his stroke. In fact, with a suite of at least 50 words, he could even transmit up to 1,000 complete sentences.

Earlier generations of neuroprostheses have relied on communications from the brain to the limb or hand muscles to activate letters on a keyboard. Messages are relayed around the unresponsive muscles to a processor that translates them into single-letter keystrokes. As with using head movements, word production is slow and tedious and often

produces just a few words a minute. Now researchers have decoded the origin of brain signals controlling speech and created the new neuroprosthesis that facilitates the production of whole words, yielding a faster word-per-minute rate.

“This is a big step, one big step among many that we’ll be able to take,” says Vikash Gilja, an associate professor of electrical and computer engineering at the University of California, San Diego, who was not involved in the study. A key advance, he says, is the “incredible proof of concept” that someone who has been unable to speak for more than

a decade and a half can still generate speech signals to use with these interfaces.

“This was not like an overnight kind of thing, where we just plugged it in,” says the study’s senior author Edward Chang, chair of neurosurgery at the University of California, San Francisco. He and his colleagues first spent many years sorting out how the brain controls speech-related muscles, pinpointing the messages and movements associated with each vowel and consonant in the English alphabet. When they launched the BCI Restoration of Arm and Voice (BRAVO) study to test the 128-electrode brain implant they had developed, the first participant was the man who had suffered a stroke at age 20, who goes by the pseudonym “Bravo-1.”

He worked through 50 sessions of a half hour or so each during 81 weeks of the study. In the sessions, researchers would present a target word or sentence on a screen. When Bravo-1 engaged his brain to send the related speech signals, the processor picked them up through the implanted electrodes and transmitted their message to a computer. The computer side of the

device decoded Bravo-1’s messages correctly 74.5 percent of the time (logging more than 90 percent accuracy occasionally)—and it produced a median rate of about 15.2 words per minute.

That is, of course, nowhere near the fluidity of a fast-talking teenager. Achieving better performance and accurate message decoding will require combining the high accuracy of devices that signal through the upper limb and this “critical demonstration that the speech signals are present and that they can be leveraged,” Gilja says.

Chang says that for his group, the next steps are to see “if this is better, worse or the same in more people,” while the researchers also use a larger vocabulary to train the machine that decodes the brain’s output. The vocabulary has already expanded beyond the 50 words reported in this study, he says, and “it’s exciting to see things grow in that kind of way.”

When asked about how Bravo-1 responded to the success he’s experienced so far, Chang says, “I think he was really thrilled and excited, and this is really just the beginning.”

—Emily Willingham

## It’s Not You, It’s COVID: Couples Who Blamed Pandemic for Tensions Stayed Happier

**Pinning stress on the coronavirus helped couples cope and remain resilient**

Whether it’s a work deadline, traffic jam, leaky roof or broken-down car, everyday stressors can undermine relationships. Routine annoyances tend to weigh on people, using up energy and making them more likely to lash out at a partner—even when the partner is clearly not to blame for the problem at hand.

But the COVID-19 pandemic is nothing like a demanding boss or a delayed train. It has upended the world, hammered national economies and dominated headlines for more than a year—making it a pretty conspicuous target for negative sentiments. Now a study published in *Social Psychological and Personality Science* shows that when couples blamed their daily stressors

on the pandemic, each person ended up happier with their partner despite the unprecedented burdens brought on by the disaster.

“Stress turns us inward and exhausts us,” says lead author and relationship researcher Lisa Neff of the University of Texas at Austin. This exhaustion can indirectly harm a romantic relationship, a phenomenon called stress spillover. But the effects of blaming stress on bigger problems—such as a natural disaster or a serious medical diagnosis—have long been unclear, Neff says. Some studies show that stress spillover occurs; others find that couples actually report greater satisfaction with their partners.

Couples are much more aware of big stressors as they happen, Neff explains. Such events are usually all-consuming and easy to point to as reasons for feeling irritable or unhappy. “Under those conditions, people might use the stressor as a scapegoat,” she says. Even though the pandemic is a once-in-a-century kind of event, Neff says, there are past analogues, such as the 2007–2009 financial crisis. “During that time, people tended to blame the poor economy for the problems in their



relationship,” she explains. A 2011 study found that such people reported feeling happier with their partner than couples who blamed each other for their day-to-day money problems.

To test if a similar phenomenon occurred in the time of COVID, Neff and her colleagues surveyed 191 participants for 14 days in April and May 2020. Members of the group, which included 81 couples and 29 individuals who had a partner but were participating without that person, answered questions about the sources of their stress and how satisfied they were with their relationship. The researchers then repeated the two-week survey last November and December and analyzed the responses. The team found that people generally blamed the pandemic for their daily stress more than they blamed themselves or their partner. When participants reported that stress was caused by the pandemic, they also reported higher satisfaction with their relationship.

Neff says she was surprised to observe that the benefits of pandemic scapegoating lasted for months. “We thought, as the situation lagged on, maybe people would forget about [the pandemic], or the stress would

become too much,” she says. “But even in our follow-up wave, it was still beneficial.” Neff posits that because their follow-up occurred in November and December 2020, COVID-19 was still at the top of participants’ minds as they considered how to travel for and celebrate the holidays.

“This is a really novel application to understanding relationships in the time of COVID,” says Arizona State University researcher Ashley Randall, who studies how couples cope with stress and was not involved with the new study. But she adds that this work does not present a complete picture. “There are important limitations with respect to the study’s demographics,” she says. For instance, the participants were mostly white and well educated, and only 16 percent reported a reduction in work hours and pay. People who lost their job or could not pay their bills might have experienced pandemic stress differently than those who remained financially secure. Concurrent events, such as high-profile incidents of police brutality and a rise in anti-Asian rhetoric and violence, could have also affected stressors for nonwhite couples, Randall notes.

Additionally, the analysis did not



include any same-gender couples. Neff says her calculations suggested women might experience greater benefits than men, but she cautions

that because more women than men participated in her investigation, these results might not be significant. In earlier studies of how the pandem-

ic affected relationships, women reported greater emotional distress and a harder time maintaining a healthy work-life balance than men. Although Neff is not planning to probe the question of gender because of limitations of her sample set, she is now studying whether confinement and loss of alone time during COVID lockdowns actually brought couples closer together rather than driving them apart.

Even if pandemic scapegoating helped couples feel happier with their partner at the end of each day, is it healthy for people to blame all their relationship problems on external forces? “It’s easier for us to look outside of ourselves, whereas that ability to take and recognize ownership [is harder],” whether COVID is the stressor or not, Randall says.

Both Neff and Randall say this research shows how couples who present a “united front” against a shared stressor can move through tough times by reframing problems as obstacles to tackle together. Learning how to identify and verbally communicate those stressors can help relationships stay resilient, Randall says. “These strategies are important—[in the] pandemic and beyond,” she adds.

—Tess Joosse

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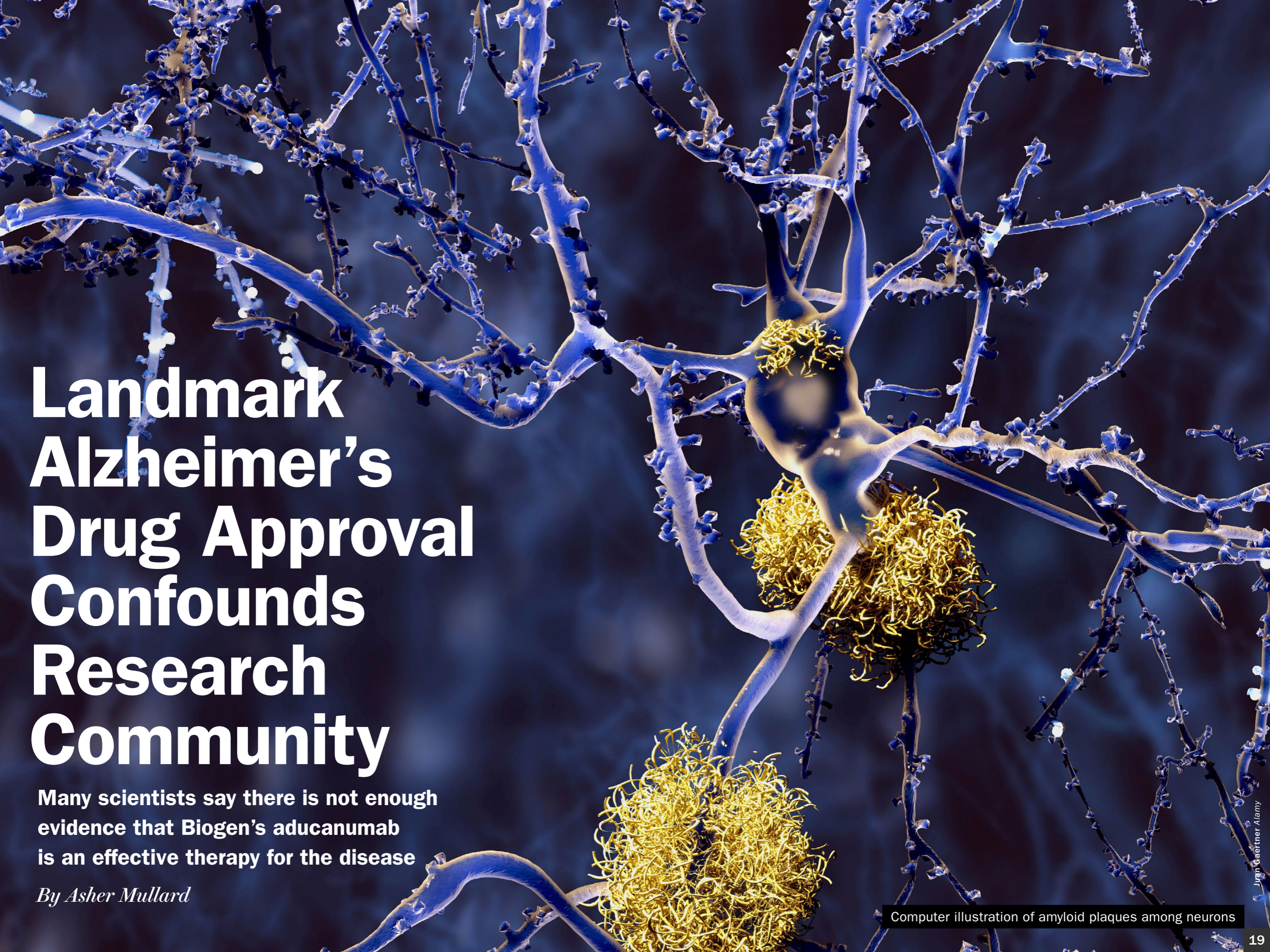
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# Landmark Alzheimer's Drug Approval Confounds Research Community

Many scientists say there is not enough evidence that Biogen's aducanumab is an effective therapy for the disease

*By Asher Mullard*

Computer illustration of amyloid plaques among neurons

The U.S. Food and Drug Administration's approval in June of the first new drug for Alzheimer's disease in 18 years was welcomed by some patients looking for hope against an intractable condition. But for many researchers it came as a surprise—and a disappointment.

Aducanumab—developed by biotechnology company Biogen in Cambridge, Mass.—is the first drug approved that attempts to treat a possible cause of the neurodegenerative disease rather than just the symptoms. But the approval has sparked a contentious debate over whether the drug is effective. Many experts, including an independent panel of neurologists and biostatisticians, advised the FDA that clinical-trial data did not conclusively demonstrate that aducanumab could slow cognitive decline.

The FDA instead relied on an alternative measure of activity, which sets a dangerous precedent, some researchers warn.

Current Alzheimer's drugs address only disease symptoms, for instance, delaying memory loss by a few months. Aducanumab clears out clumps of a protein in the brain called amyloid- $\beta$ , which some researchers think is the root cause of Alzheimer's. This theory is known as the amyloid hypothesis. The FDA approved the drug on the basis of its ability to reduce the levels of these plaques in the brain.

"This is a very slender reed on which to hang an approval decision," says Jason Karlawish, a geriatrician

and co-director of the Penn Memory Center in Philadelphia. Despite the dominance of the amyloid hypothesis over the past decades, evidence that links reductions in plaque levels to improvements in cognition is "thin, at best," Karlawish says.

"Desperation should drive the funding of science, not drive the way we interpret the science," he says.

### DESPERATE NEED

But some patient groups are desperate for anything that might offset the effects of the incurable, progressive disease. Estimates suggest that 35 million people worldwide have this form of dementia.

"History has shown us that approvals of the first drug in a new category invigorates the field, increases investments in new treatments and encourages greater innovation," said Maria Carrillo, chief science officer for the patient advocacy group Alzheimer's Association in Chicago, in a statement. "We are hopeful, and this is the beginning—both for this drug and for better treatments for Alzheimer's."

Others worry that the approval will have the opposite effect—stymieing research efforts. Karlawish suspects

that Alzheimer's patients might start dropping out of ongoing clinical trials to take aducanumab. Others worry that drug developers might abandon other targets. If demonstrating amyloid-lowering activity is enough to win regulatory approval, it might discourage developers from focusing on the big cognitive benefits that patients need, some scientists says.

"This is going to set the research community back 10 to 20 years," says George Perry, a neurobiologist at the University of Texas at San Antonio and a skeptic of the amyloid hypothesis.

### PROBLEMATIC DATA SET

Aducanumab, an intravenously infused antibody, is the latest in a long line of therapeutic candidates that aims to tackle amyloid plaques. But although every drug of this type has so far failed to improve cognition, questions have persisted about whether amyloid- $\beta$  was the right drug target, as well as whether researchers were testing the optimal therapeutic candidates, the correct doses or the appropriate patients.

"The problem with most of the amyloid trials is that they didn't disprove anything," says Bart De Strooper, director of the U.K. Dementia Research Institute. "They just proved that a drug, in the way it was applied, didn't work."

Researchers' concerns now center on aducanumab's tumultuous passage through clinical trials and the resulting data set, which is incomplete and unpublished.

The FDA's approval is based on data from two phase III

trials. In March 2019 researchers peeked at interim data while these trials—which were conducted in early-stage Alzheimer’s patients—were ongoing. They concluded that these were unlikely to succeed, and Biogen halted both trials early.

But months later the biotech firm brought the antibody back from the brink, after inspecting the data more closely. Cognitive decline slowed in a statistically significant way in the subset of patients who received the highest dose of aducanumab, Biogen’s reanalysis showed. Aducanumab did not show the same benefit when used at a lower dose in this trial, and it didn’t show a benefit at any dose in the other trial.

For Paul Aisen, director of the University of Southern California’s Alzheimer’s Therapeutic Research Institute, the totality of the data supports approval. “My personal view is that aducanumab is an effective therapy,” says Aisen, who consults for Biogen. “But this was a problematic data set. It was a very fraught situation,” he concedes.

These tensions were on display last November at an FDA meeting to discuss the trial data. An independent panel of experts advising the FDA evaluated the data and argued strongly against Biogen’s assertion that the partial positive trial results carried more weight than the negative ones. Scott Emerson, a biostatistician at the University of Washington who was on the panel, called the approach akin to “firing a shotgun at a barn and then painting a target around the bullet holes.”

The data also showed that aducanumab also has non-negligible side effects. Around 40 percent of treated patients in the two phase III trials developed brain swelling. Most of these patients don’t suffer any symptoms related to the swelling, but they need regular brain scans to avoid dangerous complications—a burden for patients, neurologists and health-care systems.

At the November meeting, 10 out of 11 panelists ultimately voted that the presented data could not be con-

**“My personal view  
is that aducanumab  
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But this was a  
problematic data set.  
It was a very  
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*—Paul Aisen*

sidered as evidence of aducanumab’s effectiveness; the other abstained. In June the FDA reached the opposite conclusion.

#### POSTAPPROVAL TRIAL

As a condition of the FDA’s approval—which relied on the agency’s accelerated approval program—Biogen now must run a postmarketing trial to confirm that the drug can improve cognition. It has yet to release details on when and how this trial will take place. Biogen has up to nine years to complete the trial.

This worries industry watchers. “Experience shows that relying on accelerated approval to gather timely, high-quality postapproval evidence is not necessarily a given,” says Aaron Kesselheim, who studies pharmacoeconomics at Harvard Medical School and is a member of the FDA panel that discussed aducanumab.

The FDA’s choice to grant accelerated approval to aducanumab—after a roller coaster of a clinical-trial program—could have broader implications, too. “This opens the door to drug companies seeking to use the accelerated approval program as a way of getting drugs on the market based on extremely low-quality evidence or post hoc data fishing,” Kesselheim says.

#### RIPPLE EFFECTS

Biogen is now in line for a major windfall with aducanumab; its share price jumped by 40 percent on the approval.

Some experts had expected the FDA to approve the antibody only for patients with early-stage disease, but the regulator has not limited its use—any Alzheimer’s patient can receive it. Biogen says that it will charge around \$56,000 a year per person for the drug. If 5 percent of the U.S.’s six million Alzheimer’s patients receive the treatment, the drug’s revenue would reach nearly \$17 billion a year. This would make it the second top-selling drug, by current revenues.

The Institute for Clinical and Economic Review, a non-profit organization, estimates a cost-effective price is \$2,560 to \$8,300 a year.

The approval is also likely to shake up the development of future Alzheimer’s drugs, researchers say.

With a pathway to approval established, drug developers are likely to double down on anti-amyloid drugs. Drug companies Eli Lilly, Roche and Eisai are already in phase III trials with anti-amyloid antibodies. They, too, might now be able to secure approvals with evidence of amyloid-lowering activity, regardless of their effects on cognition.

Before the approval, the research community had started to shift toward other drug targets associated with Alzheimer’s. For instance, more than 10 drug candidates now in clinical trials are designed to clear another toxic protein from the brain, called tau.

David Knopman, a neurologist at the Mayo Clinic in Rochester, Minn., hopes that these and earlier-stage efforts won’t falter as a result of aducanumab’s win, based on amyloid-lowering activity. “We need to look at other targets,” he says.

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A person adds flowers to a memorial that has pictures of some of the missing from the partially collapsed 12-story Champlain Towers South condo building on June 28, 2021, in Surfside, Fla. The pictures were placed on the fence as the search for loved ones went on.

# Ambiguous Loss from Miami-Area Condo Collapse Makes Grieving Harder

In a Q&A, loss expert Pauline Boss talks about coping with extreme uncertainty in the wake of a disaster

By Katherine Harmon Courage



Joe Raedle/Getty Images

**A**s the morning of June 24 dawned, just hours after a large portion of the Champlain Towers South condominium building in Surfside, Fla., had collapsed, more than 150 people were unaccounted for. Despite nearly around-the-clock search-and-rescue efforts for more than 10 days—apart from a brief pause while the remainder of the building was demolished for safety reasons—as of July 5, some 117 people remained missing. How do those whose loved ones are still missing cope with such devastating uncertainty?

Many are likely experiencing an emotional purgatory known as ambiguous loss, a state in which people have a sense of potential loss—but without the certainty that would allow them to begin grieving and recovering.

To learn more about this psychologically painful—yet surprisingly common—experience, *Scientific American* spoke with Pauline Boss, a professor emeritus in the department of family social science at the University of Minnesota and a clinician. Boss coined the term in the 1970s and detailed it in her 1999 book *Ambiguous Loss: Learning to Live with Unresolved Grief*. In the discussion, she explained why the recent collapse of the Miami-area building sets a textbook stage in which people are stuck in this psychological limbo, why “closure” is the wrong thing to expect, and how the pandemic has put so many of us into milder forms of ambiguous loss.

[An edited transcript of the interview follows.]

***How do events such as the Miami-area condo collapse—in which the fate of a loved one may remain uncertain for a period of time—impact the grieving process?***

When someone is missing, it freezes the grieving process—that is, you don’t have societal support to grieve. So you’re isolated, which makes it even worse.

***In what way does this tragedy in Florida fit with your concept of ambiguous loss?***

Sadly, it is an exact example of ambiguous loss, just as 9/11 was, just as soldiers missing in war is and kidnapped children are. Ambiguous loss is very, very common, unfortunately. And it is the most difficult kind of loss because it’s complicated by not knowing, by not having the usual facts. It’s in the gray area, the shadowland.

As time goes on, however, I’m sure that hope [of finding loved ones alive] is weakening. And that, too, is a process that is helped by facts, such as DNA evidence. After 9/11 in New York City, DNA evidence helped those who had lost loved ones a great deal.

***What are some of the ramifications of ambiguous loss?***

It can lead to depression and the immobilization of all of our daily processes—going to work and that kind of thing. Very often terrorists have found that kidnapping hurts the family and community more than killing people because the ambiguity is the worse torture.

But what I have found is that many of the people I

have worked with over time—after a tsunami in Japan, after 9/11, and so on—find a way through to resilience, which is surprising. To live with not knowing, they shift to a “both and” kind of thinking whereby they may still keep a glimmer of hope—that someday the soldier will come walking out of the jungle or that someone will have been absent from this building in Miami and will turn up somewhere else. And they also move forward with life without that person. That takes a little time, however. Sharing a narrative, sharing your story with others who had the same kind of loss, appears to be helpful. It certainly was helpful after 9/11.

The research shows that grief does not have to end and that setting time lines has been harmful in the grief process. We learn to live with grief. That grief appears in oscillations—to and fro, in and out, up and down—but these oscillations come farther and farther apart as time goes on.

***What are some other helpful ways to learn how to live with ambiguous loss that your research and practice have shown?***

It is helpful to tell people that what they are experiencing is ambiguous loss, it’s the most stressful kind of loss there is, and it’s not their fault. Those are the three lines I use around the world, wherever I work with this kind of situation.

***About four days after the collapse, the mayor of Surfside was still saying that he was holding out***

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***hope of finding more survivors. (Humans can typically only survive for a few days without water.) Is it helpful or harmful for people to keep hoping that their loved ones will still be found alive even when the evidence begins to mount that the worst is likely true?***

It's a balancing act at first: if there's a reality of some people still being alive, then it's correct for officials to say they're holding out hope. But then there comes a time when one must say, "There probably is no one living anymore." And it's tough for officials to decide when that is. But families can handle the truth. And they do better over time if they hear the truth. That can help them give up the old hope—which is that this person will be found—and formulate a new hope, a new purpose. For example, that could be making sure this doesn't happen to someone else or doing something in honor of the missing person.

We also need to be patient with these families. We want closure, but "closure" is the most cruel word that could be used. I hear it already on the news: "They need closure. They need to find the bodies." When they find the bodies, people still won't have closure. They will remember this person and this trauma forever. And so we've got to give up on that word. What we really want instead of closure is certainty: "We would like some certainty about our loved ones and where their remains are or if they're dead or alive." Closure is a misnomer.

***How is grieving different for those whose loved one's remains are not found?***

The grief is very different. And in fact, grief therapy doesn't work. It's more a stress-management intervention, managing the ambiguity and managing the not knowing. It is very different from when you have an elderly grandfather who dies. That's sad, too, but you have the facts in front of you. These people may not have it until there's DNA evidence. And until that time, what they need to do is try to increase

their tolerance for ambiguity, which is not easy because we want certainty in things. And we can do that best by using both-and thinking: "He's probably dead—and maybe not." And so the rest of us need to have patience with people who may say, "I saw him walking in a crowded street." That seems to happen a lot with people who have loved ones who are missing. And that's what they do instead of grieving. They're not ready to grieve until they know for sure.

***Has the pandemic made ambiguous loss more common?***

Yes. And the general public named it themselves because there were many losses—such as loss of trust in the world, a loss of being able to see their loved ones except on video calls, loss of being able to be with someone in the hospital or in a nursing home. There really was nothing we could do. We just had to learn how to live with being out of control, being surrounded by uncertainty. [Editor's Note: Boss's forthcoming book *The Myth of Closure: Ambiguous Loss in a Time of Pandemic and Change* covers this subject in more detail and will be released this fall.]

***How could public officials—and the media—better handle these sorts of events in the future to reduce the harm to those who might be experiencing this type of loss?***

First of all, and most important, do not use the word "closure." It is painful for people to hear. Second, be patient with their reactions, which may include anger. It's a normal outcome of not knowing. And finally, I would say educate yourself about ambiguous loss, because it's more common than you think. **M**



# How Did Neandertals and Other Ancient Humans Learn to Count?

Archaeological finds suggest that people developed numbers tens of thousands of years ago. Scholars are now exploring the first detailed hypotheses about this life-changing invention

*By Colin Barras*



Prehistoric accounting? Markings made on a hyena bone by a Neandertal might have recorded numerical information.

S

ome 60,000 years ago, in what is now western France, a Neandertal picked up a chunk of hyena femur and a stone tool and began to work. When the task was complete, the bone bore nine notches that were strikingly similar and approximately parallel, as if they were meant to signify something.

Francesco d’Errico, an archaeologist at the University of Bordeaux in France, has an idea about the marks. He has examined many ancient carved artifacts during his career, and he thinks that the hyena bone—found in the 1970s at the site of Les Pradelles near Angoulême—stands out as unusual. Although ancient carved artifacts are often interpreted as artworks, the Les Pradelles bone seems to have been more functional, d’Errico says.

He argues that it might encode numerical information. And if that’s correct, anatomically modern humans might not have been alone in developing a system of numerical notations: Neandertals might have begun to do so, too.

When d’Errico published his ideas in 2018, he was venturing into territory that few scientists had explored: the ancient roots of numbers. “The origin of numbers is still a relatively vacant niche in scientific research,” says Russell Gray, an evolutionary biologist at the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany. Researchers don’t even agree, at times, on what numbers are, although a 2017 study defined them as dis-

crete entities with exact values that are represented by symbols in the form of words and signs.

Now the origin of numbers is attracting increasing attention as researchers from a variety of fields address the problem from different vantage points.

Cognitive scientists, anthropologists and psychologists are looking at contemporary cultures to understand differences among existing number systems—defined as the symbols that a society uses for counting and manipulating numbers. Their hope is that clues buried in modern systems might illuminate details of their origins. Meanwhile archaeologists have begun looking for evidence of ancient numerical notations, and evolutionary biologists with an interest in language are exploring the deep origins of number words. These studies have spurred researchers to formulate some of the first detailed hypotheses for the prehistoric development of number systems.

And an infusion of funding will stimulate more studies in this area. This year an international research team with a €10-million (U.S. \$11.9-million) grant from the

European Research Council will start to test different hypotheses, as part of a broader effort to study when, why and how number systems appeared and spread around the world. The project, called the Evolution of Cognitive Tools for Quantification (QUANTA), might even provide insights into whether number systems are unique to anatomically modern humans or were conceivably present in nascent form in Neandertals.

#### AN INSTINCT FOR NUMBERS

Although researchers once thought that humans were the only species with a sense of quantity, studies since the mid-twentieth century have revealed that many animals share the ability. For instance, fish, bees and newborn chicks can instantly recognize quantities up to four, a skill known as subitizing. Some animals are also capable of large-quantity discrimination: they can appreciate the difference between two large quantities if they are distinct enough. Creatures with this skill could, for example, distinguish 10 objects from 20 objects but not 20 from 21. Six-month-old human infants also show a similar appreciation of quantity, even before they have had significant exposure to human culture or language.

What all of this suggests, says Andreas Nieder, a neuroscientist at the University of Tübingen in Germany, is that humans have an innate appreciation of numbers. That arose through evolutionary processes such as natural selection, he says, because it would have carried adaptive benefits.

Others interpret the evidence differently. Rafael



Núñez, a cognitive scientist at the University of California, San Diego, and one of the leaders of QUANTA, accepts that many animals might have an innate appreciation of quantity. He argues, however, that the human perception of numbers is typically much more sophisticated and can't have arisen through a process such as natural selection. Instead many aspects of numbers, such as the spoken words and written signs that are used to represent them, must be produced by cultural evolution—a process in which individuals learn through imitation or formal teaching to adopt a new skill (such as how to use a tool).

Although many animals have culture, one that involves numbers is essentially unique to humans. A handful of chimpanzees have been taught in captivity to use abstract symbols to represent quantities, but neither chimps nor any other nonhuman species uses such symbols in the natural world. Núñez suggests that a distinction should therefore be made between what he has dubbed the innate “quantical” cognition seen in animals and the learned “numerical” cognition seen in humans.

But not everyone agrees. Nieder argues that neurological studies show clear similarities between the way

in which quantities are processed in the brains of non-human animals and how the human brain processes numbers. He says that it is misleading to draw too firm a line between the two behaviors, although he agrees that human numerical abilities are much more advanced than those of any other animal. “No [nonhuman] animal is able to truly represent number symbols,” he says.

D’Errico’s analysis of the Les Pradelles bone could help to provide some insights into how the earliest stages of number systems took shape. He studied the nine notches under a microscope and says that their shapes, depths and other details are so alike that all seem to have been made using the same stone tool, held in the same way. This suggests that all were made by one individual in a single session lasting perhaps a few minutes or hours. (At some other time, eight much shallower marks were carved on the bone, too.)

D’Errico, however, doesn’t think that this individual intended to produce a decorative pattern because the marks are uneven. For comparison, he has analyzed the seven notches on a 40,000-year-old raven bone from a site of Neandertal occupation in Crimea. Statistical analysis shows that the notches on this bone are spaced with

Researchers think that people cut notches into this baboon bone some 40,000 years ago as an early form of counting.

the same sort of regularity seen when modern volunteers are given a similar bone and asked to mark it with equally spaced notches. But this type of analysis also shows that the marks on the Les Pradelles bone lack such regularity. That observation—and the fact that the notches were generated in a single session—led d’Errico to consider that they might have been merely functional, providing a record of numerical information.

### MARKS OF SOPHISTICATION

The Les Pradelles bone is not an isolated find. For instance, during excavations at Border Cave in South Africa, archaeologists discovered an approximately 42,000-year-old baboon fibula that was also marked with notches. D’Errico suspects that anatomically modern humans living there at the time used the bone to record numerical information. In the case of this bone, microscopic analysis of its 29 notches suggests they were carved using four distinct tools and so represent four counting events, which d’Errico thinks took place on four separate occasions. Moreover, he says that discov-

eries over the past 20 years show that ancient humans began producing abstract engravings, which hint at sophisticated cognition, hundreds of thousands of years earlier than was once thought.

In the light of these discoveries, D’Errico has developed a scenario to explain how number systems might have arisen through the very act of producing such artifacts. His hypothesis is one of only two published so far for the prehistoric origin of numbers.

It all started by accident, he suggests, as early hominins unintentionally left marks on bones while they were butchering animal carcasses. Later, the hominins made a cognitive leap when they realized that they could deliberately mark bones to produce abstract designs—such as those seen on an approximately 430,000-year-old shell found in Trinil, Indonesia. At some point after that, another leap occurred: individual marks began to take on meaning, with some of them perhaps encoding numerical information. The Les Pradelles hyena bone is potentially the earliest-known example of this type of mark making, says d’Errico. He thinks that with further leaps, or what he dubs “cultural exaptations,” such notches eventually led to the invention of number signs such as 1, 2 and 3.

D’Errico acknowledges that there are gaps in this scenario. It isn’t clear what cultural or social factors might have encouraged ancient hominins to begin marking bones or other artifacts deliberately or to then harness those marks to record numerical information. QUANTA will use data from anthropology, cognitive science, linguistics and archaeology to better understand those social factors, says d’Errico, who is one of the project’s four principal investigators.

### **BONES OF CONTENTION**

But QUANTA researcher Núñez, along with some researchers who are not involved in the project, cautions that ancient artifacts such as the Les Pradelles bone are

challenging to interpret. Karenleigh Overmann, a cognitive archaeologist at the University of Colorado Colorado Springs, highlights those difficulties by citing the example of message sticks used by Aboriginal Australians. These sticks, which are typically flattened or cylindrical lengths of wood, are adorned with notches that might look as though they encode numerical information—but many do not.

Piers Kelly, a linguistic anthropologist at the University of New England in Armidale, Australia, who conducted a review of message sticks, agrees with Overmann’s point. He says that some message sticks are carved with tallylike marks, but these often act as a visual memory aid to help a messenger recall details of the message they are delivering. “They call to mind the act of recounting a narrative rather than accounting a quantity,” Kelly says.

Wunyungar, an Aboriginal Australian who is a member of the Gooreng Gooreng and Wakka Wakka communities, says that the sticks might transmit one of any number of distinct messages. “Some are used for trading—for foods, tools or weapons,” he says. “Others might carry messages of peace after war.”

Overmann has developed her own hypothesis to explain how number systems might have emerged in prehistory—a task made easier by the fact that a wide variety of number systems are still in use around the world. For example, linguists Claire Bower and Jason Zentz of Yale University reported in a 2012 survey that 139 Aboriginal Australian languages have an upper limit of “three” or “four” for specific numerals. Some of those languages use natural quantifiers such as “several” and “many” to indicate higher values. There is even one group, the Pirahã people of the Brazilian Amazon, that is sometimes claimed not to use numbers at all.

Overmann and other researchers stress that there’s nothing intellectually lacking about societies that use

relatively simple number systems. But she wondered whether such societies might provide clues about the social pressures that drive the development of more elaborate number systems.

### **COUNTING ON POSSESSIONS**

In a 2013 study, Overmann analyzed anthropological data relating to 33 contemporary hunter-gatherer societies across the world. She discovered that those with simple number systems (an upper limit not much higher than “four”) often had few material possessions, such as weapons, tools or jewelry. Those with elaborate systems (an upper numeral limit much higher than “four”) always had a richer array of possessions. The evidence suggested to Overmann that societies might need a variety of material possessions if they are to develop such number systems.

In societies with complex number systems, there were clues to how those systems developed. Significantly, Overmann noted that it was common for these societies to use quinary (base 5), decimal or vigesimal (base 20) systems. This suggested to her that many number systems began with a finger-counting stage.

This finger-counting stage is important, according to Overmann. She is an advocate of material engagement theory (MET), a framework devised about a decade ago by cognitive archaeologist Lambros Malafouris of the University of Oxford. MET maintains that the mind extends beyond the brain and into objects, such as tools or even a person’s fingers. This extension allows ideas to be realized in physical form; thus, in the case of counting, MET suggests that the mental conceptualization of numbers can include the fingers. That makes numbers more tangible and easier to add or subtract.

The societies that moved beyond finger counting did so, Overmann argues, because they developed a clearer social need for numbers. Perhaps most obviously, a soci-

ety with more material possessions has a greater need to count (and to count much higher than “four”) to keep track of objects.

Overmann thinks MET implies that there is another way in which material possessions are necessary for the elaboration of number systems. An artifact such as a tally stick also becomes an extension of the mind, and the act of marking tally notches on the stick helps to anchor and stabilize numbers as someone counts. These aids could have been crucial to the process through which humans first began counting up to large numbers.

Eventually, Overmann says, some societies moved beyond tally sticks. This first happened in Mesopotamia around the time when cities emerged there, creating an even greater need for numbers to keep track of resources and people. Archaeological evidence suggests that by 5,500 years ago, some Mesopotamians had begun using small clay tokens as counting aids.

According to Overmann, MET suggests that these tokens were also extensions of the mind and that they fostered the emergence of new numerical properties. In particular, the shapes of tokens came to represent different values: 10 small cone tokens were equivalent to a sphere token, and six spheres were equivalent to a large cone token. The existence of large cones, each equivalent to 60 small cones, allowed the Mesopotamians to count into the thousands using relatively few tokens.

Andrea Bender, a psychologist at the University of Bergen in Norway and another leader of the QUANTA project, says that the team members plan to gather and analyze large amounts of data relating to the world’s numeral systems. That should allow them to test Overmann’s hypothesis that body parts and artifacts might have helped societies to develop number systems that ultimately count into the thousands and higher. But Bender says she and her colleagues are not presupposing that Overmann’s MET-based ideas are correct.

Others are more enthusiastic. Karim Zahidi, a philosopher at the University of Antwerp in Belgium, says that although Overmann’s scenario is still incomplete, it has real potential to explain the development of the elaborate number systems in use today.

### LINGUISTIC LEADS

Overmann acknowledges that her hypothesis is silent on one issue: when in prehistory human societies began developing number systems. Linguistics might offer some help here. One line of evidence suggests that number words could have a history stretching back at least tens of thousands of years.

Evolutionary biologist Mark Pagel of the University of Reading in England and his colleagues have spent many years exploring the history of words in extant language families, with the aid of computational tools that they initially developed to study biological evolution. Essentially, words are treated as entities that either remain stable or are outcompeted and replaced as languages spread and diversify. For instance, English “water” and German “wasser” are clearly related, making them cognates that derive from the same ancient word—an example of stability. But English “hand” is distinct from Spanish “mano”—evidence of word replacement at some time in the past. By assessing how frequently such replacement events occur over long periods, it is possible to estimate rates of change and to infer how old words are.

Using this approach, Pagel and Andrew Meade, also at Reading, showed that low-value number words (“one” to “five”) are among the most stable features of spoken languages. Indeed, they change so infrequently across language families—such as the Indo-European family, which includes many modern European and southern Asian languages—that they seem to have been stable for anywhere between 10,000 and 100,000 years.

This doesn’t prove that the numbers from “one” to “five” derive from ancient cognates that were first spoken tens of thousands of years ago, but Pagel says it’s at least “conceivable” that a modern and a Paleolithic Eurasian could have understood one another when it came to such number words.

Pagel’s work has its fans, including Gray, another of QUANTA’s leaders, but his claims are challenged by some scholars of ancient languages. Don Ringe, a historical linguist at the University of Pennsylvania, says it isn’t clear that the stability of lower-number words can just be projected far back into prehistory, regardless of how stable they seem to be in recent millennia.

That all adds up to a slew of open questions about when and how humans first started using numbers. But despite the debate swirling around these questions, researchers agree it’s a topic that deserves a lot more attention. “Numbers are just so fundamental to everything we do,” Gray says. “It’s hard to conceive of human life without them.”

Numbers might even have gained this importance deep in prehistory. The notched baboon bone from Border Cave is worn smooth in a way that indicates that ancient humans used it over many years. “It was clearly an important item for the individual who produced it,” d’Errico says.

Not so for the Les Pradelles specimen, which lacks this smooth surface. If it does record numerical information, that might not have been quite as important at the time. In fact, although d’Errico and his colleagues have spent innumerable hours analyzing the bone, he says it’s possible that the Neandertal who chipped away at that hyena femur some 60,000 years ago spent very little time using it before tossing the bone aside.

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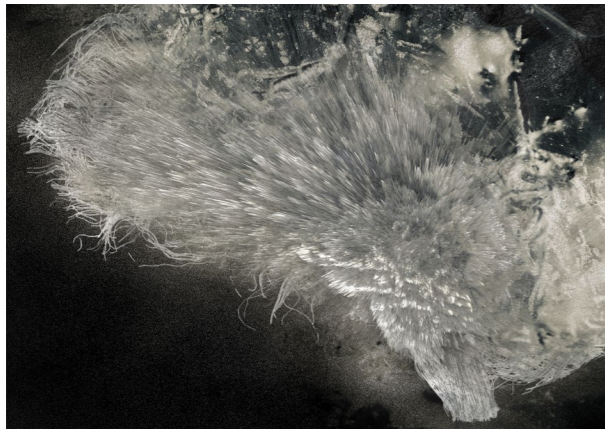
T H E  
A R T  
O F  
N E U R O S C I E N C E

# Inspired by Chronic Illness, She Made Award-Winning Art about the Brain

*Scientific American* presents the winner and honorable mentions  
of the 11th annual Art of Neuroscience contest

*By Maddie Bender*

T H E  
A R T  
O F  
N E U R O S C I E N C E



Winner

*Cognition IX*,  
from the series  
The 8th Sense.

WHEN YAS CRAWFORD started feeling the effects of her chronic illness, she says she felt as if her body and mind were at war. “When you’re ill for a long time, your body takes over,” she says. “Your brain wants to do one thing, and your body does something else.”

Crawford has myalgic encephalomyelitis, also called chronic fatigue syndrome. She says her illness made her ruminate on interoception, the perception of the body’s internal state. People with this condition, particularly those who are afflicted for a long time, report heightened awareness of their body’s inner workings—such as their heartbeat and temperature.

We commonly think of five senses—sight, sound, smell, touch and taste—and we have the senses of balance and body position as well. But interoception could be called an “eighth sense,” argues Craw-

ford, who has a background in geology and microbiology and a master’s degree in photography. That title inspired her to make an eponymous collection of artwork. *Cognition IX*, an image from that collection, recently won the [2021 Art of Neuroscience competition](#) held by the [Netherlands Institute for Neuroscience](#).

Now in its 11th year, the Art of Neuroscience showcases the intersection of art and neuroscience through multimedia. Static images make up the works recognized in the competition’s early years, but more recent submissions have included videos, sculptures and even interactive online poetry.

*Cognition IX* showcases Crawford’s experience in film photography and digital editing with a black-and-white image of a seascape in the approximate shape of a brain. From the rough region of where the brain stem meets the thalamus—the structure that relays sensory signals to the cerebral cortex—individual fibrils appear to explode outward. The image is in equal parts ordered and disordered: the fibers

snake around one another on the outside of the beanlike shape and shoot out in near parallel closer to its center.

Crawford says her art is meant for others with chronic illnesses who resist being defined by them. Intertwining the internal and external lives of a person is a theme in her work.

Honorable mentions of the competition represent a variety of formats and media: a sculpture, mini documentary, mapping installation and scored video.

The sculpture *Change of Heart* (변심), by recent Davidson College graduate Adrienne Lee, tackled the theme of neural degeneration with a metal-and-paper representation of Purkinje cells, which are specialized neurons that play a role in coordination, learning and movement. Degenerative diseases are “akin to an act of betrayal against the beauty of one’s accumulated life experiences,” Lee writes in her artist’s statement. The metalwork forming the dendrites of the Purkinje cells incorporates letters from the Korean alphabet, a nod to Lee’s personal

Maddie Bender is a 2021 AAAS Mass Media Fellow at *Scientific American*. She recently received an M.P.H. in microbial disease epidemiology from the Yale School of Public Health.

history. Her studio art degree and neuroscience minor have informed her other work, too, including a [steel brain-shaped sculpture](#) that is big enough to encircle a viewer’s head.

Another honorable mention piece is *The Brainwave Project*, by Qi Chen, an instructor at Wuhan Textile University, which explores the artist’s project to stimulate the brains of people in a minimally conscious state and communicate the results to their family with artwork. She created a device to convert brain waves into images and make an otherwise sterile readout accessible and meaningful to onlookers. Chen synthesized her journey designing and testing the devices in a five-minute documentary, calling it an integration of “functional art and art therapy.”

Independent artist Guihan Lu created *Self Evolution*, an installation that plays with theater and self-portraiture by projecting images recorded from a brainwave kit that slowly morph into a recognizable representation of the viewer. She

## Honorable Mention

*Change of Heart* (변심).

says she was inspired by Abraham Ortelius, a 16th-century Flemish cartographer who created the modern atlas, which he entitled *Theatre of the World*. Lu's project was awarded an honorable mention and transforms the inner workings of the mind into an immersive video and performance—an observable spectacle.

Sarshar Dorosti, affiliated with the Tehran University of Art in Iran, composed a video entitled *Fractal Brain*. Fractals are mathematical figures with motifs that repetitively occur at smaller scales—in other words, a never-ending pattern. Fractal geometry is found throughout nature, in objects such as a fern frond and a head of Romanesco. *Fractal Brain* displays stills and animations of fractals overlaid with eerie, metallic droning noise. In February, Dorosti was first author of a preprint study that investigated the brain's response to fractal animations. **M**





**Melissa J. Coleman** is a professor of neuroscience at the W. M. Keck department of science at Scripps College. **Eric Fortune** is a neurobiologist at the New Jersey Institute of Technology's department of biological sciences.

NEUROSCIENCE

# The Neuroscience of Taking Turns in a Conversation

**Research in birds suggests that when one partner speaks, the other partner's brain is inhibited from talking over them**

A fundamental feature of vocal communication is taking turns: when one person says something, the other person listens and then responds. Turn taking requires precise coordination of the timing of signals between individuals. We have all found over the past year using Zoom that disruptions of the timing of auditory cues—like those annoying delays caused by poor connections—make effective communication difficult and frustrating. How do the brains of two individuals synchronize their activity patterns for rapid turn taking during vocal communication?

In a recently published paper we studied turn taking in a specialist, the plain-tailed wren (*Pheugopedius euophrys*), which sings precisely timed duets. Our findings demonstrate the ability to coordinate relies on sensory cues from one partner

that temporarily inhibit vocalizations in the other. These birds sing duets in which females and males alternate their vocalizations, called syllables, so rapidly it sounds as if a single bird is singing. These wrens live in dense bamboo on the slopes of the Andes. To study the neural basis of duet singing, we flew to Ecuador where we load-

ed up a (*Pheugopedius euophrys*), which sings precisely timed duets. Our findings demonstrate the ability to coordinate relies on sensory cues from one partner that temporarily inhibit vocalizations in the other. These birds sing duets in which females and males alternate their vocalizations, called syllables, so rapidly it sounds as if a single



White-browed sparrow weavers in Kenya

bird is singing. These wrens live in dense bamboo on the slopes of the Andes. To study the neural basis of duet singing, we flew to Ecuador where we loaded up a truck with equipment and drove to a remote field site: the Yanayacu Biological Field Station and Center for Creative Studies. Much of our equipment required electricity, so we brought car batteries for backup and a six-meter copper rod that we drove into the mountain earth for our electrical ground. Our “lab bench” was a door we placed on two Pelican suitcases.

First, we had to catch pairs of wrens, so we hacked through bamboo with machetes and set up mist nets. We then attracted pairs to the nets by playing the duets of wrens. To see how neurons responded during duets, we surgically implanted very small wires into a specific region of the brain, called HVC. Neurons in this region are responsible for producing the song—that is, they are premotor—and they also respond to auditory signals. To transmit the neural signals (that is, action potentials) to a computer, a small wireless digital transmitter was connected to the wires. We then had to wait for the birds to sing their remarkable duets.

During duet singing, the number of action potentials increased when each bird sang its part of the duet. A similar finding has been made in another duetting bird from Africa, the white-browed sparrow weaver. But we found that when each bird heard its partner, the number of action potentials decreased below baseline: the brain was inhibited.

In a final set of experiments, as an indirect test that HVC was inhibited while hearing the partner, the birds were anesthetized with a substance that

blocks inhibitory neurotransmission in the brain. With inhibition blocked, hearing the partner’s syllables produced an increase in the number of action potentials in HVC. This experiment gave us more evidence that auditory cues from the partner, revealed under anesthesia, inhibit the song premotor circuitry in HVC when the birds are awake.

Inhibition is an interesting mechanism for turn taking because it prevents the two birds from singing over each other. In addition, similar to bouncing on a trampoline, the inhibition creates the ability to “rebound,” or respond more quickly, which may contribute to the rapid alternation of syllables. Taken together, the alternating activity between the two birds is driven by an auditory link between the two. That is, there is an increase in activity in the female HVC that produces her syllable. This signal is perceived by the male and inhibits activity in HVC, preventing him from singing. HVC activity then rebounds, producing the male syllable, which in turn is perceived by the female and inhibits her brain. Similarly, during a Zoom call with auditory delays, our brains are inhibited when we finally hear what someone is saying. This disrupts our speech pattern and makes taking turns difficult.

This study also suggests that when individuals are interacting in a shared behavior they act as a single entity. This concept is important for any group of organisms cooperating to produce a shared behavior that is more than the sum of its parts; for example, several people playing in a band. To coordinate their behavior, the brains of all participants must link together to become a single unit.

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**David H. Rosmarin** is an associate professor at Harvard Medical School and director of the McLean Hospital Spirituality & Mental Health Program. He received his Ph.D. from Bowling Green State University and certification in clinical psychology from the American Board of Professional Psychology.

MENTAL HEALTH

# Psychiatry Needs to Get Right with God

**By not making more of an effort to incorporate spirituality in treatment, we are doing a disservice to patients**

In the early days of the pandemic, economist Jeanet Bentzen of the University of Copenhagen examined Google searches for the word “prayer” in 95 countries. She identified that they hit an all-time global high in March 2020, and increases occurred in lockstep with the number of COVID-19 cases identified in each country. Stateside, according to the Pew Research Center, 55 percent of Americans prayed to end the spread of the novel coronavirus in March 2020, and nearly one quarter reported that their faith increased the following month, despite limited access to houses of worship.

These are not just interesting sociological trends—they are clinically significant. Spirituality has historically been dismissed by psychiatrists, but results from a pilot program at McLean Hospital in



Massachusetts indicate that attention to it is a critical aspect of mental health care.

In 2017 my multidisciplinary team of mental health clinicians, researchers and chaplains created Spiritual Psychotherapy for Inpatient, Residential and Intensive Treatment (SPIRIT), a flexible and spiritually integrated form of cognitive-behavioral therapy. We subsequently trained a cadre of more than 20 clinicians, stationed on 10 different clinical units throughout McLean Hospital, to deliver SPIRIT and evaluated the approach. Since 2017 SPIRIT has been delivered to more than 5,000 people. Our results suggest that spiritual psychotherapy is not only feasible but highly desired by patients.

In the past year American mental health sank to the lowest point in history: Incidence of mental disorders increased by 50 percent, compared with before the pandemic, alcohol and other substance use surged, and young adults were more than twice as likely to seriously consider suicide than they were in 2018. Yet the only group to see improvements in mental health during the past year were those who attended religious services at least weekly (virtually or in-person): 46 percent report “excellent” mental health today versus 42 percent one year ago. As former congressional representative Patrick J. Kennedy and journalist Stephen Fried wrote in their book *A Common Struggle*, the two most underappreciated treatments for mental disorders are “love and faith.”

It’s no wonder that nearly 60 percent of psychiatric patients want to discuss spirituality in the context of their treatment. Yet we rarely provide such an opportunity. Since Sigmund Freud’s characteri-

zation of religion as a “mass delusion” nearly 100 years ago, mental health professionals and scientists have eschewed the spiritual realm. Current efforts to flatten the COVID-19 mental health curve have been almost entirely secular. The American Psychological Association’s extensive set of consumer resources makes no mention of spirituality. And the Centers for Disease Control and Prevention’s only spiritual recommendation is to “connect with your community- or faith-based organizations.” Of more than 90,000 active projects currently funded by all 27 institutes and centers within the National Institutes of Health, fewer than 20 mention spirituality anywhere in the abstract, and only one project contains this term in its title. Needless to say, a lack of funding for research on spirituality hamstrings clinical innovation and dissemination.

This situation goes beyond separation of church and state. Health-care professionals falsely disconnect common spiritual behaviors and experiences from science and clinical practice. As a result, we ignore potential spiritual solutions to our mental health crisis, even when our well-being is worse than ever before.

My own research has demonstrated that a belief in God is associated with significantly better treatment outcomes for acute psychiatric patients. And other laboratories have shown a connection between religious belief and the thickness of the brain’s cortex, which may help protect against depression. Of course, belief in God is not a prescription. But these compelling findings warrant further scientific exploration, and patients in distress should certainly have the option to

include spirituality in their treatment.

Recently one of my patients—an ostensibly secular 22-year-old woman—presented with an uptick in depression and anxiety. She reported feeling “defeated” and stated that she was losing hope of ever getting better. My research has taught me that many secular individuals believe in something, and I therefore assess for spirituality with all patients irrespective of their religious affiliation or lack thereof. In that context, this particular patient shared with me that she believed in God and also believed that she was brought to this earth for a specific purpose. Over the course of just three sessions focused on these ideas, she came to a sense of increased hope that she could overcome her life challenges, and her symptoms of depression started to abate.

In another case, a devout Christian man in his mid-60s came to McLean Hospital with severe depression and acute levels of suicidality. His treatment team was aware of his faith but unclear about how to address it in therapy. I was asked to consult with the patient, who reported to me that he was struggling to pray and think about God in the throes of his depression. We scheduled times for prayer and religious study, and I encouraged conversations with his pastor. Within one month his depression began to remit for the first time in more than a year.

Countless anecdotes of this nature occurred during a recent year-long clinical trial of SPIRIT that my research team completed with funding from the Bridges Consortium (supported by the John Templeton Foundation). More than 90 percent of pa-

tients reported experiencing some kind of benefit, regardless of religious affiliation.

The study also revealed key opportunities in patient care, particularly for younger and seemingly secular patients. Psychiatric folklore has long suggested that psychotic, manic and obsessive patients gravitate more toward spirituality, as do older adults. Our findings, however, suggest that patients benefited from SPIRIT irrespective of their diagnosis or age. Depressed millennials seem just as likely to want and benefit from spiritual psychotherapy as geriatric patients.

Our results also suggest that spiritual care is not only for religious individuals. The largest group of patients to voluntarily attend SPIRIT (39 percent of our sample) were individuals with no religious affiliation at all. Apparently many nonreligious people still seek spirituality, especially in times of distress. In fact, such individuals may be most likely to attend spiritual psychotherapy because their spiritual needs are otherwise ignored. In this vein, recent declines in church membership may increase the need for spiritual care.

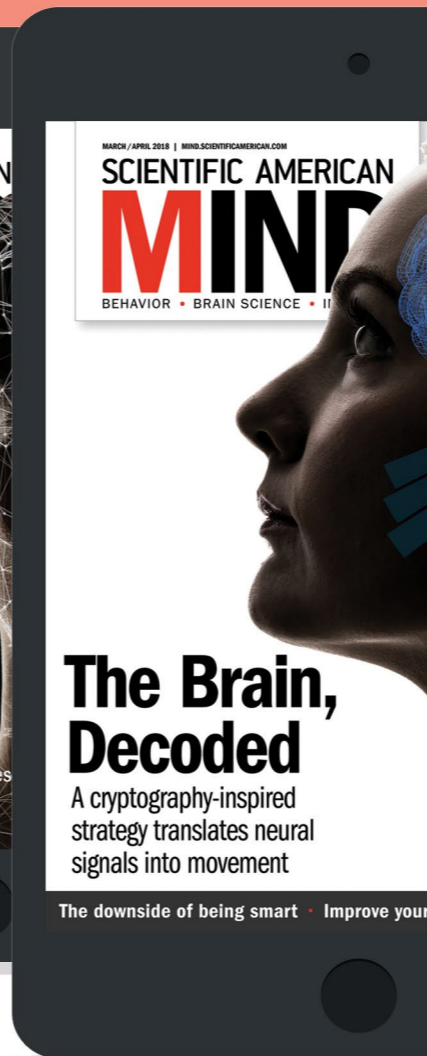
Perhaps most interesting, patients responded better to SPIRIT when it was delivered by religiously unaffiliated clinicians. This surprising finding suggests that secular clinicians may be particularly effective in providing spiritual treatment. This is good news because psychiatrists are the least likely of all physicians to be religious.

It remains to be seen whether God can solve our mental health crisis. But the potential clinical benefits of spirituality and patients' desire for spiritual treatments provide a reason to believe.

# From Genius to Madness

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**Yasser Abu Jamei** is a psychiatrist working in Gaza and director of Gaza Community Mental Health Program.

MENTAL HEALTH

# A New Mental Health Crisis Is Raging in Gaza

Recent bombings by Israel have caused more than just physical trauma

“Have you ever seen a six-month old-baby with exaggerated startle response?” One of my colleagues who works on our telephone counseling service was asking me for advice on how to respond to several distraught mothers seeking to help their babies who had started showing such distressing symptoms of trauma during the recent bombing. Our telephone service was back and responding to callers on the third day of the attacks on Gaza, though of course with certain difficulties.

The question took me back 20 years to when I was a young resident in the pediatric department at Nasser hospital in Khan Younis, Gaza’s second biggest city, in the southern part of the Gaza Strip. My plan then was to become a pediatrician. The hospital, on the western side of the city, was not far from the Israeli settlements. Often in the middle of the night I used to receive mothers arriving



Civil defense workers pore through rubble on May 16, 2021, in the aftermath of an Israeli bombing.

in the pediatric emergency department with tiny children who had started screaming with no clear reason. Physical examination mostly revealed nothing abnormal. Perhaps this was the trigger that made me train to become a psychiatrist.

During those nights, you could often hear shooting from inside the Israeli settlement’s high fortifications, with the bullets mostly ending in the walls of the Palestinian homes and other buildings that faced the settlements. That was the common

experience we adults were used to, and of course something that children, even the very youngest, also had to live with.

Thinking about those mothers and babies, I then asked myself about the likely psychological consequences of this 11-day offensive on the people of the Gaza Strip and how it is going to be different from 2014's Gaza war which lasted for seven weeks through July and August, including a ground invasion into Gaza. There were then 2,251 Palestinians killed and 11,000 wounded.

#### AFTER THE 2014 WAR

In 2014 we formed in the Gaza Community Mental Health Program (GCMHP) what we called crisis response teams, which were usually composed of a man and a woman, both psychologists. Their main task was to provide Psychological First Aid: to give some psychological support and detect and refer cases in need of further interventions to our three community centers. Parents often were talking about changes that their children had begun experiencing. Children were having poor concentration, sleeping difficulties and night terrors, bed-wetting and irritability. Younger children were clinging to their parents.

During the four months that followed the attacks in 2014, 51 percent of children visiting our centers were diagnosed with post-traumatic stress disorder (PTSD), and another 11 percent were diagnosed with bed-wetting. For adults, 31 percent were diagnosed with PTSD, while 25 percent were diagnosed with depression. During those months, almost 20 percent of the people who were visited

by the crisis teams were referred to our community centers for further assessment and therapy. The United Nations Children's Emergency Fund (UNICEF) reported then that more than 370,000 children were in need of mental health and psychosocial intervention. Would these figures predict anything for after the 2021 offensive?

#### ELEVEN DAYS

We know now the physical effects: at least 242 people were killed in Gaza, including 66 children, 38 women (four pregnant) and 17 elderly people. The injured are around 1,948 people—an iconic figure for every Palestinian. It includes 610 children, 398 women and 102 elderly people. Moderate to severe injuries affect 25 percent of the injured. During the offensive 107,000 people were internally displaced with about two thirds of them seeking shelter at United Nations Relief and Works Agency schools.

We saw six hospitals and 11 clinics damaged, and there are some ironic stories. It was on May 17 that the Rimal primary health-care center situated within the Ministry of Health (MoH) compound in Gaza city was attacked. The center included the main laboratory for COVID-19 tests and was partially affected. The MoH had to stop the testing and asked people who were supposed to get their second shot of vaccine to go to Al-Daraj primary health-care center across Gaza City. That center, too, came under attack, however, as there was a house in the area that was bombed in an air strike. The Rimal clinic was also the place to get vaccinated in Gaza City. Luckily the damage to

both clinics was partial, and the Rimal clinic soon resumed service. But a young physician, Majed Salha, was severely injured on his head, and his condition was critical.

#### ONGOING MENTAL HEALTH CHALLENGES

Only weeks before, COVID was the main concern in Gaza as in any other place in the world. People calling our telephone counseling line at GCMHP or people we were meeting either in the community or at the community centers presented with two main and interlinked complaints or challenges. One was how deeply the economic conditions were affecting their lives. The unemployment rate in Gaza, even before the bombings, was 43.1 percent, and for people under 30 it was 65.5 percent. Even among those working, many are in casual employment, living from hand to mouth. Taxi drivers or those who sell vegetables at the open markets were badly affected by the COVID-related restrictions on movement and other measures such as social distancing and closing of some of those open markets. Depression and high anxiety were rife as men were unable to provide either sanitizers or simply food for their families.

The second fear was always how to deal with their children under such restrictions and with schools closed. We have on average five children per household, and we live in one of the most crowded areas in the world with more than 13,000 persons in one square mile. Those children, not being allowed to leave their homes because of COVID restrictions, were badly in need of support.

Two weeks before the offensive the MoH was

dealing with the second wave of COVID with about 35 to 40 percent of the people being tested showing positive results. Suddenly, those COVID-related concerns were overshadowed by the fears related to the air strikes, the bombing and survival. How is that going to impact the psychological well-being of the population?

### AN UNPRECEDENTED EXPERIENCE

In one night, it was reported, 160 warplanes attacked 450 targets in less than 40 minutes in northern areas of the Gaza Strip. The strikes happened at the same time as 500 artillery shells were fired. People from outside Gaza asked us if this experience was similar to what happened in 2008 when the first strike took place. On Saturday, December 27, 2008, at around 11:20 A.M., suddenly people in the whole Gaza strip were overwhelmed with the sounds of bombardment and the view of a huge mushroomlike smoke plume that was all over the place. It was a moment where children were either going to schools (afternoon shift) or returning from schools (morning shift), and everyone really was in a state of shock. At that moment about 60 fighter planes carried the first attack in less than one minute. People asked us whether this felt the same. Perhaps it looks the same, but there is a critical major difference.

In 2008 the bombing was a single minute or two minutes, and it was across the whole Gaza strip (140 square miles). But what happened in these 11 days is entirely different. The strikes continued for about 25 to 30 minutes or sometimes up to 40 minutes in the same city or geographical

area. You could hear continuous bombing in your own city, in your own small geographical area, that continued for about 25 to 40 minutes. In all that time neither you nor your children nor your wife nor any other family member would feel that they could take even a single breath.

The continuous bombardment and shelling that continued in different cities on different nights meant that no one really could feel any moment of safety. All of us had our nervous system at its very highest alarm level for more than 25 and up to 40 minutes. I can say that this is the most fearful experience that I have had throughout four large offensives over the years.

This type of attack caused extreme fear in the population of two million, traumatizing almost everyone.

Another key difference to keep in mind is that most of the areas that were attacked were in the heart of the cities. We witnessed the flattening of 13- or 14-story towers and many other buildings. Some families were just eliminated during those attacks. In Al-Shati camp one family had 10 people killed, including eight children and two women. Fourteen families lost more than three members, and some of them were killed outright.

The fear and terror that we lived with through the 11 days was something unprecedented. So do we expect to see more people and with a similar diagnosis to 2014, or 2012, or 2008? Maybe, but definitely the lower number of people who were killed or injured does not indicate a lesser psychological impact on the population. We already see children presented with night terrors, and pains in

their knees and abdomen, and parents report clinging sons and daughters. Men and women alike complain of joint pains, low back pain and difficulty in concentration. Many say that they are not sure if they are living a big dream or a reality. And the worst-affected people show severe psychological effects, including dissociative symptoms. In any case, we will need more time to have a better understanding of the impact.

One might think that this will be our only concern, but that is not the case. In the first few days after the ceasefire with COVID testing resumed, only a few hundred tests were made, but on average one third of the results were positive. Tens of thousands of people were displaced and stayed in school classes or at their relatives' homes, making the whole community inevitably much more mixed and crowded. As you may imagine, COVID measures were not all carried out.

Our hospitals are already full of injured people, and the health system is struggling. And it seems that we are on the verge of a third COVID wave. A wave where out of the two million people only 40,000 have been vaccinated. We have just escaped the hell of air strikes to find the hell of COVID-19 at our doors. We are moving from living under occupation and offensive to life under occupation and blockade, with COVID.

Ours is a life that you will never understand unless you are a resident of Gaza. Outsiders love to call us resilient human beings rather than see our reality. As English poet T. S. Eliot wrote in 1936, "humankind cannot bear very much reality."



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POLICY & ETHICS

# Science Should Not Try to Absorb Religion and Other Ways of Knowing

Our diverse ways of seeing reality will never, and should never, meld into a monolithic worldview

An edgy biography of Stephen Hawking has me reminiscing about science's good old days. Or were they bad? I can't decide. I'm talking about the 1990s, when scientific hubris ran rampant. As journalist Charles Seife recalls in *Hawking Hawking: The Selling of a Scientific Celebrity*, Hawking and other physicists convinced us that they were on the verge of a "theory of everything" that would solve the riddle of existence. It would reveal why there is something rather than nothing and why that something is the way it is.

In this column, I'll look at an equally ambitious and closely related claim, that science will absorb other ways of seeing the world, including the arts, humanities and religion. Nonscientific modes of knowledge won't necessarily vanish, but they will



Remnants of a Neolithic burial chamber

become consistent with science, our supreme source of truth. The most eloquent advocate of this perspective is biologist Edward O. Wilson, one of our greatest scientist-writers.

In his 1998 best seller *Consilience: The Unity*

*of Knowledge*, Wilson prophesizes that science will soon yield such a compelling, complete theory of nature, including human nature, that "the humanities, ranging from philosophy and history to moral reasoning, comparative religion, and interpretation

of the arts, will draw closer to the sciences and partly fuse with them.” Wilson calls this unification of knowledge “consilience,” an old-fashioned term for coming together or converging. Consilience will resolve our age-old identity crisis, helping us understand once and for all “who we are and why we are here,” as Wilson puts it.

Dismissing philosophers’ warnings against deriving “ought” from “is,” Wilson insists that we can deduce moral principles from science. Science can illuminate our moral impulses and emotions, such as our love for those who share our genes, as well as giving us moral guidance. This linkage of science to ethics is crucial because Wilson wants us to share his desire to preserve nature in all its wild variety, a goal that he views as an ethical imperative.

At first glance you might wonder: Who could possibly object to this vision? Wouldn’t we all love to agree on a comprehensive worldview, consistent with science, that tells us how to behave individually and collectively? And in fact, many scholars share Wilson’s hope for a merger of science with alternative ways of engaging with reality. Some enthusiasts have formed the Consilience Project, dedicated to “developing a body of social theory and analysis that explains and seeks solutions to the unique challenges we face today.” Last year poet-novelist Clint Margrave wrote an eloquent defense of consilience for Quillette, noting that he has “often drawn inspiration from science.”

Another consilience booster is psychologist and megapundit Steven Pinker, who praised Wilson’s “excellent” book in 1998 and calls for consilience

between science and the humanities in his 2018 best seller *Enlightenment Now*. The major difference between Wilson and Pinker is stylistic. Whereas Wilson holds out an olive branch to “postmodern” humanities scholars who challenge science’s objectivity and authority, Pinker scolds them. Pinker accuses postmodernists of “defiant obscurantism, self-refuting relativism and suffocating political correctness.”

The enduring appeal of consilience makes it worth revisiting. Consilience raises two big questions: (1) Is it feasible? (2) Is it desirable? Feasibility first. As Wilson points out, physics has been an especially potent unifier, establishing over the past few centuries that the heavens and earth are made of the same stuff ruled by the same forces. Now physicists seek a single theory that fuses general relativity, which describes gravity, with quantum field theory, which accounts for electromagnetism and the nuclear forces. This is Hawking’s theory of everything and Steven Weinberg’s “final theory.”

Writing in 1998, Wilson clearly expected physicists to find a theory of everything soon, but today they seem farther than ever from that goal. Worse, they still cannot agree on what quantum mechanics means. As science writer Philip Ball points out in his 2018 book *Beyond Weird: Why Everything You Thought You Knew about Quantum Physics Is Different*, there are more interpretations of quantum mechanics now than ever.

The same is true of scientific attempts to bridge the explanatory chasm between matter and mind. In the 1990s it still seemed possible that research-

ers would discover how physical processes in the brain and other systems generate consciousness. Since then, mind-body studies have undergone a paradigm explosion, with theorists espousing a bewildering variety of models, involving quantum mechanics, information theory and Bayesian mathematics. Some researchers suggest that consciousness pervades all matter, a view called panpsychism; others insist that the so-called hard problem of consciousness is a pseudoproblem because consciousness is an “illusion.”

There are schisms even within Wilson’s own field of evolutionary biology. In *Consilience* and elsewhere, Wilson suggests that natural selection promotes traits at the level of tribes and other groups; in this way, evolution might have bequeathed us a propensity for religion, war and other social behaviors. Other prominent Darwinians, notably Richard Dawkins and Robert Trivers, reject group selection, arguing that natural selection operates only at the level of individual organisms and even individual genes.

If scientists cannot achieve consilience even within specific fields, what hope is there for consilience between, say, quantum chromodynamics and queer theory? (Actually, in her fascinating 2007 book *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning*, physicist-philosopher Karen Barad finds resonances between physics and gender politics; however, Barad’s book represents the kind of post-modern analysis deplored by Wilson and Pinker.) If consilience entails convergence toward a consensus, science is moving away from consilience.

So, consilience doesn't look feasible, at least not at the moment. Next question: Is consilience desirable? Although I've always doubted whether it could happen, I once thought consilience should happen. If humanity can agree on a single, rational worldview, maybe we can do a better job solving our shared problems, like climate change, inequality, pandemics and militarism. We could also get rid of bad ideas, such as the notion that God likes some of us more than others or that racial and sexual inequality and war are inevitable consequences of our biology.

I also saw theoretical diversity, or pluralism, as philosophers call it, as a symptom of failure; the abundance of "solutions" to the mind-body problem, like the abundance of treatments for cancer, means that none works very well. But increasingly, I see pluralism as a valuable, even necessary counterweight to our yearning for certitude. Pluralism is especially important when it comes to our ideas about who we are, can be and should be. If we settle on a single self-conception, we risk limiting our freedom to reinvent ourselves, to discover new ways to flourish.

Wilson acknowledges that consilience is a reductionistic enterprise, which will eliminate many ways of seeing the world. Consider how he treats mystical visions, in which we seem to glimpse truths normally hidden behind the surface of things. To my mind, these experiences rub our faces in the unutterable weirdness of existence, which transcends all our knowledge and forms of expression. As William James says in *The Varieties of Religious Experience*, mystical experiences should "forbid a

premature closing of our accounts with reality."

Wilson disagrees. He thinks mystical experiences are reducible to physiological processes. In *Consilience*, he focuses on Peruvian shaman-artist Pablo Amaringo, whose paintings depict fantastical, jungly visions induced by ayahuasca, a hallucinogenic tea (which I happen to have taken) brewed from two Amazonian plants. Wilson attributes the snakes that slither through Amaringo's paintings to natural selection, which instilled an adaptive fear of snakes in our ancestors; it should not be surprising that snakes populate many religious myths, such as the biblical story of Eden.

Moreover, ayahuasca contains psychotropic compounds, including the potent psychedelic dimethyltryptamine, like those that induce dreams, which stem from, in Wilson's words, the "editing of information in the memory banks of the brain" that occurs while we sleep. These nightly neural discharges are "arbitrary in content," that is, meaningless; still, the brain desperately tries to assemble them into "coherent narratives," which we experience as dreams.

In this way, Wilson "explains" Amaringo's visions in terms of evolutionary biology, psychology and neurochemistry. This is a spectacular example of what Paul Feyerabend, my favorite philosopher and a fierce advocate for pluralism, calls "the tyranny of truth." Wilson imposes his materialistic, secular worldview on the shaman, and he strips ayahuasca visions of any genuine spiritual significance. While he exalts biological diversity, Wilson shows little respect for the diversity of human beliefs.

Wilson is a gracious, courtly man in person as

well on the page. But his consilience project stems from excessive faith in science, or scientism. (Both Wilson and Pinker embrace the term "scientism," and they no doubt think that the phrase "excessive faith in science" is oxymoronic.) Given the failure to achieve consilience within physics and biology—not to mention the replication crisis and other problems—scientists should stop indulging in fantasies about conquering all human culture and attaining something akin to omniscience. Scientists, in short, should be more humble.

Ironically, Wilson himself questioned the desirability of final knowledge early in his career. At the end of his 1975 masterpiece *Sociobiology*, Wilson anticipates the themes of *Consilience*, predicting that evolutionary theory plus genetics will soon absorb the social sciences and humanities. But Wilson doesn't exult at this prospect. When we can explain ourselves in "mechanistic terms," he warns, "the result might be hard to accept"; we might find ourselves, as Camus put it, "divested of illusions."

Wilson needn't have worried. Scientific omniscience looks less likely than ever, and humans are far too diverse, creative and contrary to settle for a single worldview of any kind. Inspired by mysticism and the arts, as well as by science, we will keep arguing about who we are and reinventing ourselves forever. Is consilience a bad idea, which we'd be better off without? I wouldn't go that far. Like utopia, another by-product of our yearning for perfection, consilience, the dream of total knowledge, can serve as a useful goad to the imagination, as long as we see it as an unreachable ideal. Let's just hope we never think we've reached it.

**Stephen Macknik** and **Susana Martinez-Conde** are professors of ophthalmology at the State University of New York and the organizers of the Best Illusion of the Year Contest. They have co-authored *Sleights of Mind: What the Neuroscience of Magic Reveals about Our Everyday Deceptions* and *Champions of Illusion: The Science behind Mind-Boggling Images and Mystifying Brain Puzzles*.

## No Shrinking Violet

How Impressionist painters made an unusual color all the rage

When Russian-American artist and cognitive scientist Allen Tager thinks about his childhood in the Soviet Union in the 1960s, his memories are violet-tinged. “We had one ink color, violet,” he reminisces, “and it was kept in glass jars that tipped over constantly. My hands, school uniform and textbooks were perpetually covered in violet stains.” Outside of the classroom, in contrast, violet was inexplicably absent from household objects and other everyday items. Years later, when Tager fell in love with the paintings of Russian artist Mikhail Vrubel (1856–1910), his fellow art students dissuaded him from creating “a similar violet harmony” and asked him to repaint the violet shades in trendier purple tones.

The ostensive unpopularity of violet versus purple nagged at the back of Tager’s mind for much of his life, eventually setting him on a 20-year journey across 193 museums in 42 countries. Tager’s search traversed time as well as space, compelling color examinations of paintings from ancient Egypt and Mesopotamia to their contemporary counterparts—and every era in



Violet wisteria flowers resting on a purple towel

## ● ILLUSIONS

between. On his quest for violet, Tager scrutinized 139,892 works of art, using 1,500 Munsell color chips as standards. The results, published in a 2018 [paper](#), were startling: barely any artworks produced before the early 1860s featured the color violet. Even old masters such as [Jan Brueghel the Elder](#) (1568–1625) and [Jan Brueghel the Younger](#) (1601–1678), who specialized in painting flowers, did not bother with the hue.

Then, the 19th-century arrival of French Impressionists in the art scene transmuted the dearth of violet in a cultural explosion. Violet burst forth in paintings and was ultimately embraced by the garment industry, becoming ever more present in ordinary clothing and other textiles. Some 50 years after critics accused Impressionists of “[violettomania](#),” the color became established in artists’ palettes. The process by which violet entered all spheres of life took more than a century, Tager asserts, and only achieved full potency in recent times.

But why do so few paintings, pre-Impressionism, include violet? Tager and color scientist collaborators Eric Kirchner and Elena Fedorovskaya [venture](#) that the explanation is neither the use of ancient roots in older paintings nor the introduction of cheaper pigments in the 1860s. Did the rarity of violet in nature play a role? Or the confusion about the terms “purple” and “violet” among speakers of English and other languages? The answer to the quandary, much like the color violet in old masters’ paintings, remains elusive.



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